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The Carrying Capacity of Flat Plates.

The construction of concrete-steel floor plates brings into prominence again the resistance of flat plates either simply supported around their edges or rigidly held after the manner of continuous beams. In the case of reinforced concrete floors these plates, usually rectangular in form, may have spans of considerable length. In fact they constitute shallow beams carrying substantial loads, except that the manner of support at their edges greatly reduces the maximum bending moment to which they would be subjected if they were simple beams. Enough tests have been made of such reinforced concrete plates to show that they possess a high carrying capacity, which, however, does not lend itself to a simple analytical treatment. From the earliest days of experimental knowledge in the field of resistance of materials it has been known that circular and rectangular plates of iron or steel exhibit surprisingly large load-sustaining power when subjected to test, as the experiments of Kirkaldy and Fairbairn show, but even up to the present time no simple formulas for the computation of those loads have been satisfactorily established. The theory of elasticity in solid bodies enables rather elaborate analyses of the stress conditions in loaded flat plates, to be written, but such analyses necessarily find application only within the elastic limit of the material, and the resulting formulas are not simple, especially when the supporting conditions at the edges and the form of plate are recognized. The fact that such an analysis is applicable only within the elastic limit will not militate against the value of an easily workable formula, for plates safely loaded would be stressed only to a degree far below the elastic limit; but it is necessary for the usefulness of a formula in engineering practice that it should be reasonably simple and easy in its application to working conditions. Such authors as Clebsch and Bach fulfil some of these conditions, but not all.

Perhaps the most common device employed in the effort to reach a reasonable formula for flat plates, especially for those of rectangular form, is to consider the plate to be divided into a great number of narrow beams at right angles to each other, one set parallel to one pair of edges of the plate and the other parallel to the other sides of the rectangle. These two sets of elementary beams are then supposed to carry such portions of the total uniform load as will make the central deflections of the two spans equal to each other. This procedure will be found to make the two portions into which the total load is divided inversely as the fourth powers of the two sides of the plate. The greater of the two bending intensities found in this manner at the center of the plate is usually, but not always, assumed to be the greatest intensity of stress in the entire plate.

This assumption, like many others made in pure analysis, simplifies the computations; indeed, the resulting simplicity and the ease with which the formula is reached frequently mislead the computer. While this operation may answer for some purposes the fact should not be overlooked that the fundamental assumption on which it is based is, on the whole, only roughly approximate, if, indeed, it can be considered approximate at all. If there were any real warrant for assuming the narrow elementary beams it would be necessary to remember that of all the infinite number of them the central two only at right angles to each other fulfil the conditions of the original assumption. Those near either side, the aggregate superficial area of which composes the greater part of the plate area, do not meet the conditions of the original assumption to any degree whatever. This is true to such an extent that any formula resulting from this loosely approximate method of treating the problem can have no real value except possibly as suggesting forms of formulas to which empirical coefficients derived from tests of full-size plates may be fitted.

Analytical investigators by this approximate method appear to overlook the fact that the pressure around the edge of the plate, when the latter is loaded well below the elastic limit, must be nearly uniform. Indeed, it may even be that the greatest intensity of stress in any rectangular plate does not much exceed that in a square plate whose side would be equal to the smaller dimension of the oblong rectangular plate. However that may be, even the most elaborate analysis yet made can not be considered much more than suggestive of the form of formula to which empirical coefficients may be fitted. Any formula sufficiently rational for the realization of that practical purpose cannot fail to possess great practical value.

The old experiments of Kirkaldy and Fairbairn appear to indicate that the requisite thickness of a metal plate varies as the eight-tenths power of the load carried, but the number of tests was altogether too small to furnish a proper basis for a formula. What is imperatively needed in this class of structural members is, first, a rational analysis of the stress conditions existing in loaded flat plates, brought into reasonably simple and workable form for edges either simply supported or made continuous with the supporting mass; and, second, a series of adequate tests of full-size plates with different conditions of loading and of varying dimensions. Such a series of tests when properly analyzed and used in connection with the rational formula, would yield just the empirical coefficients required to give these formulas an exact quantitative character and real practical value.

The Capacity of Chimneys.

Experience has shown that a chimney 125 to 150 ft. high produces a sufficient draft for the requirements of ordinary factory boilers. The force of the draft in such a stack with flues of proper construction connecting the boilers to it is from 0.5 to 0.75 in. of water, depending upon the temperature of the flue gases and attending conditions. A draft represented by 0.5 in. of water pressure is sufficient to work a horizontal return tubular boiler far above the maximum capacity at which the type is rated. With the best class of bituminous coal, such as that found in the Clearfield region of Pennsylvania, it enables the fuel to be burned under boilers of suitable proportions and with good firing at the rate of 20 lb. for each square foot of grate surface per hour, which corresponds to a rate of evaporation of something over 4 lb. of water per square foot of heating surface per hour. On this basis a boiler-horse-power on the A. S. M. E. rating is developed with from 6 to 7 sq. ft. of heating surface. Boilers are seldom rated at less than 12 sq. ft. of heating surface per horse-power, and, consequently, the force of draft indicated is sufficient to work this type to about double its nominal capacity. Hence a chimney 125 ft. in height is sufficient to meet all the demands of stationary boilers in common use. A reserve force of draft which enables a boiler to be worked to double its rated capacity not only suffices for ordinary good practice, but it would seem also to be sufficient for any abnormal conditions which might arise in special cases.

Most of the chimneys commonly used for mill purposes are less than 150 ft. in height. Occasionally, however, one is found which is 200 or even 250 ft. high and there are instances of much greater heights for special purpose, due to hills or the necessity of keeping offensive fumes far above the ground. Chimneys of unusual height are also applied to boilers of unusually large capacity, and the idea has gained some footing that it is necessary to have greater altitude for a large plant than for a small one. It may be that a chimney in a large establishment is more consistent, as the architect sees it, if its height corresponds to the magnitude of the buildings which surround it; but this consideration is one which does not appeal to the engineer. The engineer seeks to obtain ample draft for the boilers without unnecessary investment of money. A tall chimney calls for extra cost of construction. Between a chimney having a diameter of 5 ft. and one having a diameter of 6 ft., there is a difference in capacity of 50 per cent., the areas in these two examples being in the proportion of 1 to 1½. The relative cost of the two structures does not vary much from the proportion of the circumferences of the two circles, and these are as 1 to 1 1-5. An increase of capacity amounting to 50 per cent. in these two examples is thus attained by an increase of cost of 20 per cent. If, on the other hand, the capacity of the smaller chimney is increased 50 per cent. by adding to the height instead of increasing its diameter, it is necessary to make it at least twice as high. Considering the extra depth and area of foundation required, the additional thickness of walls necessary to support the addition, and the increase of height itself, the cost of this method of increasing the capacity is more than double the cost of the original structure. In one case an addition of 20 per cent. to the cost and in the other of more than 100 per cent. is necessary to produce the same results. Between the two methods of obtaining the increased capacity, the engineer has but one choice and that is to consider simply the main object for which the chimney is provided. Looking at the practical end in view, moderately high chimneys of ample flue area secure all the draft that good boilers can successfully utilize. The chimney of extreme height and extravagant cost can do no more.

The Design of Steel Roof Trusses.

The tendency toward special arrangement of manufacturing buildings has made it necessary of late to pay more attention to the design of steel roofs than has usually been given to them. Most mill architects have standard drawings and specifications for such work, and pay very little attention to it in consequence. The proportion of cases in which special designs must be made is increasing, however, and it is not uncommon to have to make allowances for exceptional weights, vibration and even impact in roof trusses just as in bridges. Consequently it is even more true now than when the subject was discussed a number of years ago in this journal, that roofs must be designed to meet load conditions that are characteristic of individual buildings, precisely as railway bridges are designed to meet their characteristic conditions. In this connection it should be borne in mind that assumed loads for buildings are almost invariably greater than the loads which they actually carry, and while this observation is less applicable to roofs than to other portions of buildings, it is still measurably true for roof trusses.

With these conditions in view it becomes a question whether to use pin or riveted connections at the joints. Pin joints are undoubtedly points of flexibility, and inasmuch as the ends of tension members are always so designed as to make the full section of the bar available for the resistance of stress, that class of members for pin-connection trusses is invariably the lighest that can be employed. Further than that, it is customary to credit tension bars with a greater capacity for resistance than the net sections of shapes. The nature of the material formerly used for portions of some shapes justified the discrimination to some extent, but the practice is not warranted in connection with the use of structural steel. The quality of the metal in all portions of steel shapes is identical with that in flats and rounds, and there are some reasons why working stresses in net sections should be a little in excess of those for flats and rounds rather than less. The avoidance of excess of section and the high working stresses allowed in the latter unite to aggravate the objectionable characteristics of very light members.

The presence of such light members indicates the possibility of excessive vibration under any moving load or under wind pulsations. When it is also considered that roof loads and spans are generally of such magnitude as to require comparatively small sections, even in the largest members, it becomes apparent that pin joints in roof trusses carry with them the conditions requisite for the maximum flexibility and vibration. It is too frequently thought to be a matter of indifference, if such a condition prevails. As a matter of fact, however, in view of the comparatively small sections that are inevitably found in roof trusses, the system of design should be such as to produce the greatest possible stiffness, and that result cannot be attained with pin joints. Numerous pin-jointed roof trusses have been designed and constructed in the past, but in many cases it has been the single purpose of the design to afford the greatest possible immediate economy of metal with practically no regard to the real ultimate economy.

A roof truss with riveted joints necessitates the use of shapes which give to all tension members some capacity for resisting compression, so that every member possesses the maximum degree of stiffness, even though it be a tension bar, instead of the greatest possible flexibility for perhaps half the members of the truss. The joints being secured, each by a group of rivets, contribute their influence toward the maximum total stiffness. There are found, then, in such trusses all the conditions demanded for the greatest possible degree of rigidity with a correspondingly enhanced capacity to resist impact, erratic loads and vibrations. Hence the tensile working stresses may be safely taken even higher for riveted roof trusses than for those with pin connections, and under proper design the difference in immediate economy of metal will not be much, if any, in favor of the pin connections, while excellence of structure and ultimate economy will be found with the riveted joints.

Ventilation of Boiler and Engine Rooms.

With the approach of the summer, ventilation readily suggests itself as an appropriate topic for discussion. So much has been said on the subject with reference to boiler and engine rooms aboard ship, where the temperatures at all times rise to extraordinary heights, that its importance in connection with similar installations on land has almost been overshadowed. Temperatures considerably above 100° are not at all uncommon during the warm months of the year in many of the basements and sub-basements of large buildings in which boilers and engines are located, and the means which have been adopted in some cases to afford relief to the engineers and firemen have generally proved entirely inadequate to produce measurably successful results.

The engine and fire-room ventilating plant in most instances consists simply of one of the several makes of exhaust fans, often too small for the work to be done, poked away in some corner chosen more with reference to convenience of installation than with a view to securing the best possible circulation of air. The impression, in fact, seems to be general that an exhaust fan will work well in whatever place it may be put; that it has a charm in itself which will cool the surrounding atmosphere, and that, at most, all that is necessary to make it successful is to provide it with an outlet and to revolve it at a convenient speed. The outcome of all this is that by far the larger number of engine and boiler rooms in large city buildings are about as uncomfortable places as one can well imagine, although, with a little forethought and rational consideration, they could be maintained at temperatures at which life would cease to be a burden to their inmates.

Where blowers are used to supply large quantities of air to different parts of a building, it has been found a good plan to have adjustable openings in the main air ducts where they traverse the engine room. From these openings a good supply of fresh air can be kept within reasonable limits. A rather unique case of engine and boiler-room ventilation provided for the removal of the heated air from a point near the ceiling, through a duct and blower, discharging into the ash pits under the boilers and thus forcing the fires. Forced draught for the boilers had been contemplated for some time in the establishment in question, and the plan just mentioned suggested itself as a convenient one of killing two birds with one stone, so to speak. The heated air removed from the engine room, it will be noticed, was not wasted, but was turned to good account in promoting combustion in the furnaces, which it did with much better effect than an equal quantity of cooler air would have secured.

Every place to be ventilated and cooled, however, has its special conditions which should govern the choice of plan, and what will serve excellently in one case will not always do the same in another; but with a reasonable amount of intelligence and judgment the problem of making the average engine and boiler room fairly comfortable ought to be easily and successfully solved.

Some Structural Lessons of the San Francisco Disaster.

The fire in San Francisco, like that in Baltimore, teaches that for very tall buildings nothing is safe except absolutely perfect fire-proof construction, and that it can be built. Nothing in Baltimore withstood the fire better than good red brick laid in cement mortar, while bricks in lime mortar were in loose heaps, as bright and clean as new. Some of the testimony elsewhere in this issue gives the same comment on San Francisco conditions.

In San Francisco the soil is somewhat like that in Philadelphia, consisting of dry, coarse sand with a little clay, which gives it sufficient adhesion to stand well in deep cuts. It has been the custom to make many of the foundations of large continuous masses of concrete which virtually form thick slabs under the entire area of the buildings. These, it is probable, will in the future be modified by the introduction of steel reinforcement to develop the full capacity of the foundation. Grillage foundations in general may be considered as a sort of make-shift, confessing by their presence that supplementary construction is necessary to utilize a poorer bearing medium than is really demanded for the substructure. On general principles the foundations should be carried down to a satisfactory stratum or be as deep as possible. Piles are satisfactory when they can be well driven and when the ground water insures their preservation by constant saturation, and concrete piles offer many advantages not yet fully realized. In all cases where the possibility of earthquakes is apprehended, the superstructure should be securely anchored to the foundations in order to omit no possible safeguard.

The present steel-cage framework for tall buildings is unquestionably the best adapted to resist fire or earthquake shocks and can be made absolutely safe by the adoption of a few modifications of standard practice for such conditions as have recently occurred in San Francisco. The most important one is in the provision of diagonal rods bracing the interior columns. The wall columns are usually sufficiently braced by the hollow tile wall construction, which, when 12 or 15 in. thick, adds enormously to the stiffness of the building. This is often demonstrated in practice by the fact that five or six stories of unbraced steelwork are quite flexible until the walls are built, when they become very rigid. The use of bricks, hollow tile, concrete and various forms of special floor and wall construction may be combined advantageously with a steel skeleton to resist main stresses of the building, and its weight should be carried by steel members which can be designed with precision to meet the exact requirements and at all times give definite well-known results. It is probable that reinforced concrete construction will deservedly play a more important part in buildings, but it should be designed with care in accordance with the requirements and conditions of the structure and should not be used indiscriminately. Particular skill and care are also necessary for its proper construction in the field.

A tall office building is a very complex structure, which should unquestionably be designed by an engineer who equates the scientific, mechanical and structural requirements, while the architect provides for the exterior motive, the artistic features and the general scheme of arrangement, thus clothing the skeleton and securing its embellishment. The engineer should not merely design the steel framework, but should analyze the functions and construction of the completed building, making suitable provision for the independent operation and the relationship of all its different features, such as the framework, bracing, floors, walls, foundations, elevators, power plant, electrical, hydraulic and sanitary installations, and all other important features, so that each one shall be properly provided for and shall not interfere with any of the others.

It is of special importance that the grillage foundations for tall and heavy buildings should not be placed on the surface of the sand stratum in large cities, because the day is undoubtedly not far distant when they will be in danger of undermining by the construction of numerous subways and tunnel systems under and around them. There is no doubt that many of the tall buildings in Chicago will have to be taken down or underpinned before they would otherwise be rebuilt on account of the tunneling under them. This is an important subject in Chicago, on account of the large number of raft foundations which have been built there in previous years. At present the tendency there is to construct concrete foundation piers in open shafts carried to rock by the well-known method of placing short sections of vertical sheeting outside the reaction rings. These piers have been carried down to a depth of 116 ft. or more and will probably be used to secure existing foundations that were designed as rafts or grillages.

Notes and Comments.

Letting Contracts to the Lowest Bidder is so customary in city work that it is interesting to note that under certain circumstances the courts will refuse to require it. In a case that recently arose in Bayonne, N. J., a paving contract was awarded to a company which bid on Trinidad asphalt. The tender was about $40,000, but there was another bid about $225 lower from a contractor offering a brand of asphalt for which only one testimonial was presented and about which none of the city authorities knew very much. Under the circumstances the tender calling for Trinidad asphalt was accepted, as the material had been widely used with satisfactory results in that section of the State. The lowest bidder appealed the case to the courts, and the Supreme Court has just handed down a decision stating that where there is no requirement in the charter of a city, or in any general law, requiring improvement contracts to be let to the lowest bidder, the municipal body has large discretion in the premises, the exercise of which will not be reviewed in the absence of proof of bad faith or fraud.

The Revenue Tax on Denatured Alcohol is something that ought to be removed in the interests of industries of many kinds. The agitation to bring about its removal is one that deserves support. Just at the present time it is difficult to see who is served by the tax except the Standard Oil Company, and as that corporation is understood to be so situated that it can get along without a tax on all materials competing with its products there is really no reason for the ban on denatured alcohol. The latter will serve as a substitute for many of the purposes for which high-priced gasoline is now used and will enable American inventors and manufacturers to develop the field of alcohol motors, which is now practically closed to them. Certain lines of manufacturing will also be much aided by the removal of the internal revenue tax on this material, for it will give them a cheap raw material in place of one that is relatively expensive.

The Applied Science Reference Room, recently established by the Pratt Institute Free Library in Brooklyn, is a novelty in library management that deserves hearty encouragement. In any city where there are numerous industries, questions are arising daily in the shops which books, trade catalogues and periodicals will answer and this reference room has been stocked to answer as many of these questions as possible. Nearly a hundred trade and scientific papers are here filed, over fifty labor-union papers, the Patent Office Gazette and a large collection of trade catalogues. The collection of books is intended to cover thoroughly electrical engineering, textile manufacture, plumbing, industrial chemistry, gas engineering, the design and management of power plants and other subjects too numerous to mention here. The books in this room are not allowed to be taken away, but duplicates of many of them are to be had in the circulating library. A special feature is made of a collection of mounted drawings of machines and mechanical devices. A man looking up a new form of chuck, for example, will find a score of illustrations of different chucks and among these may discover some that will be of service to him. The room is open every week day from 12:30 to 9:30, and can be consulted in the morning by making special application. It is in charge of Mr. Edwin M. Jenks, who reports that the success of the venture is surprising.

The Planning of a City never offered greater opportunities for magnificent results than those now possible at San Francisco. The city was laid out by men who had no regard for the future and no respect for civic beauty, even if they knew what the term meant. As it developed the condition remained the same until recently. Chinatown was allowed to grow like a cancer in the heart of the city; the possibilities which the hills of the city afforded in the way of street arrangement so as to obtain handsome vistas and good "fire-breaks" were neglected. The result was a city of little beauty, although it might have been made much more attractive without any additional expense. For about two years the improvement of the San Francisco street plan has been studied by Mr. D. H. Burnham for the Merchants' Association. He laid out a new city, which it would have been enormously expensive to reconstruct from the old one. Since his plans were completed fire has cleared the ground of many of the structures which were obstacles to the execution of his plans, and others have been so injured that their reconstruction will probably cost almost as much as their complete rebuilding. Under these circumstances it is highly desirable that before the renewal of San Francisco's burnt district begins on a permanent scale, steps should be taken to ascertain whether its plan can be modified to advantage. It is now proposed to have Congress guarantee a great issue of bonds at a low rate of interest, the proceeds to be used in the reconstruction of the city. Whether this proposal is advisable is something The Engineering Record does not feel qualified to discuss, but it is suggested that if this plan is followed it might be well to insist that the work of rebuilding should be carried out in conformity with a carefully considered general street plan, whereby the appearance of the city will be benefitted.

Selling Water Meters has been one of the lines of work carried on by The Engineering Record since its first bow to the public in 1877. It has been interested in this business not because of the meter itself, but on account of what it would accomplish. The waste of water in American cities is merely one instance of national carelessness about little things and national objection to economy. As an engineering journal, preaching sound technical and business management of water-works, this paper has from the first recognized that the meter was the greatest cure for water waste in this country. A careful study of methods of preventing waste in all the large European cities led The Engineering Record to decide many years ago that the system of frequent house-to-house inspection followed abroad was not suited to American conditions, although useful on occasions to ascertain where meters are imperatively needed. Apart from these considerations the meter stands for something very dear to all Americans, an absolutely square deal. Where every service is metered it is certain that every consumer is paying for only the amount of water he uses, which is as it should be. Where meters are not used it is tolerably certain that four-fifths of the consumers are paying for a good deal more water than they take, owing to the waste of the careless people, who are generally about one-fifth of the number in the community. It is not necessary to discuss the matter at greater length in this place, because the purpose of this note is to call attention to the help rendered by a meter manufacturer in this campaign for the square deal. It often happens to preachers of public improvements that those who benefit most from the preaching are the worst offenders against the doctrines advocated. It is the common experience of an editor to advocate something which is a manifest advance in the art, only to find that after he has helped to establish a market the manufacturer makes products of such a poor character that the opportunity for an improvement in public conditions and for business advantage to the manufacturer is lost before there has been a good trial of the innovation. In their early days meters were expensive and the temptation to skimp their quality in order to cut their price was very great. Largely through the influence of Mr. John C. Kelley, president of the National Meter Co., the American water meter has been an excellent instrument from its early days. He made it as good as he could, even when its future was clouded with uncertainty, and his steadfast adherence to this policy has been vindicated by the success of his company, which celebrated last week the construction of its 500,000th meter. In the many years The Engineering Record has been advocating the prevention of water waste it has had no stronger ally than this gentleman, who steadfastly refused to hurt the important industry in which he was a pioneer by the manufacture of inferior products. This journal does not believe that because a man who has played an important part in molding water-works' management happens to be a manufacturer there is any reason for keeping his name out of its editorial pages, and it accordingly desires to extend to him its congratulations on the results of his years of work and study, which were so fittingly celebrated last week.

UNDERPINNING THE MARSHALL FIELD BUILDING IN CHICAGO.

The Marshall Field & Co. retail department store in Chicago occupies an entire city block, 342 x 385.5 ft. in plan, with the exception of an 8-story building, covering a small site at one corner of the block. The department store is at present in 4 separate buildings. The oldest building in the group is an 8-story and basement structure, 151 x 161 ft. in plan, which was built in 1873. Adjoining this old building on the north is a building, 151 x 224 ft. in plan, with 3 floors below and 12 stories above the street grade, that was completed in 1905. Across a 40-ft. court from the old building and on the adjoining corner of the block to it is a 9-story and basement building, 151 x 120 ft. in plan, that was built in 1892. Just north of the 9-story building is a new building, 151 x 159 ft. in plan; with 3 stories below and 12 stories above the street grade, which has just been completed. The old 8-story building is being wrecked and will be replaced by a building with the same number of floors and of the same type of construction as the 1905 and the recently completed buildings. The appearance of these buildings, looking toward the old 8-story structure before the latter was wrecked, may be seen in one of the accompanying illustrations. The structure in the foreground with the clock on the corner is the old 8-story building; to the right is the 9-story building on the adjoining corner, and to the left is the 12-story building completed in 1905.

The new buildings are all built on circular concrete footings, 7 to 10 ft. in diameter, which are carried down to solid rock 110 ft. below the street grade. The new building on the site of the old 8-story structure will be carried by 52 of these concrete footings. The general methods of carrying on the excavation and building the footings for all of the new building, except those footings under its side walls, were referred to in an article in The Engineering Record for March 10, 1906, describing the novel methods of excavating building sites in Chicago that have been made possible by the service afforded by the Chicago Subway. A very important part of the retail store is located in the old 8-story building. Before that building was vacated the excavations for 40 of the concrete footings for the new building were carried down to rock and those footings brought up to the lowest sub-basement floor level of the new building, 45 ft. below the street. All of this work was carried on without interruption to business in any of the 8-story building, except the basement. The excavated material was all removed through the subway. The materials for the concrete footings and the supplies needed to shore up the old building during the construction of the latter were taken in through two 10x12-ft. shaft houses in the sidewalk along one street front of the building. These houses were the only indication at the surface of the work that was being done under the old building.

Most of the footings for the interior columns of the new building come directly under the columns carrying the 8 floors of the old building on the site. The old building columns had to be carried on shoring while the excavations were made for the footings of the new building and the concrete placed in these excavations. The loads on the columns of the old building varied from 158 to 160 tons. The old columns were hollow, cast-iron cylinders, 13½ in. in diameter and with sides 2 in. thick. They stood on spread masonry footings carried down about 7 ft. below the old basement floor level. From this old floor level down to rock 110 ft. below the street the soil varies from a semi-plastic blue clay at the top to hardpan just above the rock, with occasional pockets of sand and gravel. The old basement floor was first removed and the excavation carried down about 5 ft. below it. Shoring was then built up on two sides of each excavation for the footings under the old columns and the latter carried directly by 4 steel I-beams resting on the shoring during construction.

The arrangement of the shoring under one of these 40 columns, which is typical of that under all of them, is quite clearly shown in two of the accompanying illustrations. The span required between the two sets of shoring for each column varied from 14 to 16 ft., depending on the size of the excavation that had to be made below the latter. Each set of shoring consisted of 4 tiers of 12x12-in. timbers resting on the clay at the bottom, the timbers in two alternate tiers being placed transversely to those in the other two tiers. Above these tiers of timbers was a cribbing of 6x6-in. timbers. Two 12x12-in. timbers placed longitudinally on each of these cribs, carried the drums of jack-screws used in holding the ends of the I-beams to the proper height, two 12x12-in. timbers being placed between the screw plates and the lower flanges of the I-beams.

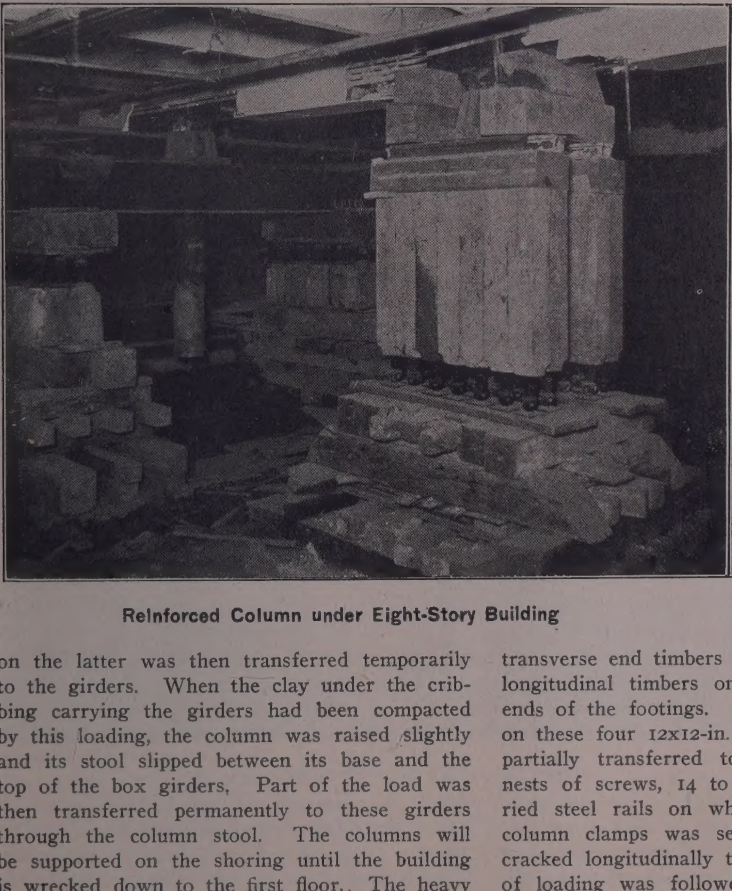
Store Buildings of Marshall Field & Co., Chicago.

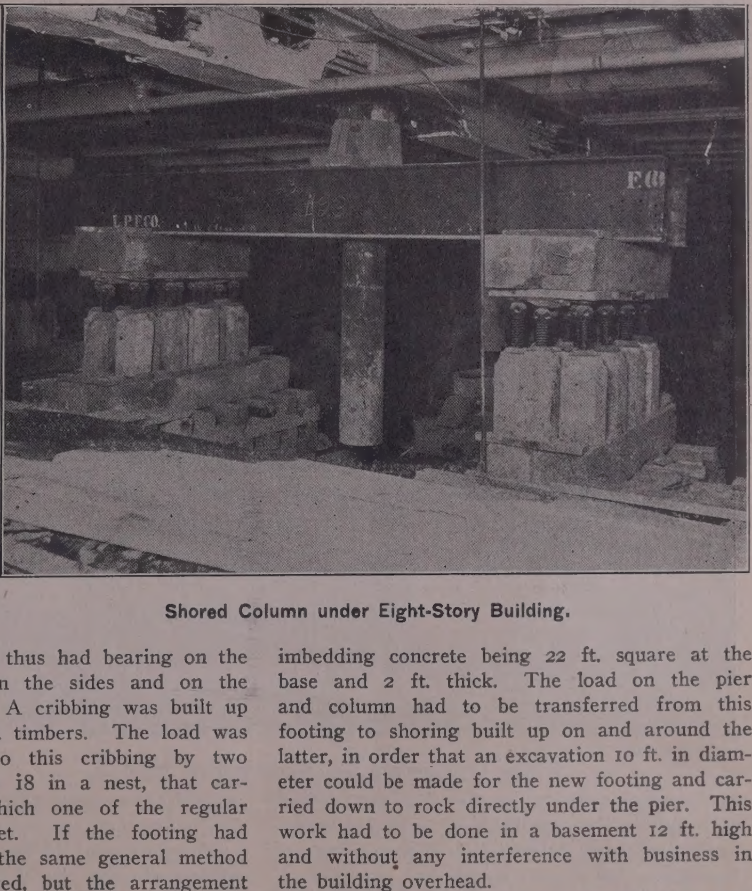
The weight of each column was transferred to the I-beams carrying it by a very heavy cast-iron clamp, the details of which are shown in one of the accompanying illustrations. The columns of the building had heavy horizontal brackets cast on the top, the brackets having triangular struts extending down to the body of the column to carry the portion of them projecting beyond the sides of the column. The clamps were divided in halves, and the halves bolted together around the column just below the bracket. Sufficient play was allowed between the two parts of the clamp to insure a firm bearing of the latter on the column and prevent any possibility of rocking. No dependence was placed, however, on the friction between the clamp and the column to carry any of the load on the latter, this load being carried entirely by a direct bearing on the top of clamp. The triangular struts under the brackets were squared off; then four square chrome steel bars, 2 in. thick, were placed under the bracket, one on each end of each half of the clamp, slots being cut in the column to receive the bars. The clamps were brought up until the tops of the bars bore against the under side of the bracket, and the column load was transferred through the bars to the clamps and the I-beams.

Each clamp was carried by four 20 or 24-in., 80-lb. I-beams, depending on the span between the cribbing on which the beams rested. The beams were placed in pairs under each end of the clamp and were carried at each end by two 12x12-in. oak timbers transverse to them on the caps of the jack-screws on the cribbing. Fourteen to eighteen screws were placed under each end of the four I-beams, depending on the load and span to be carried. These screws were placed in two rows with the drum of one screw at each end of the two rows inclined slightly toward the transverse center line of the rows, in order to prevent any possibility of the displacement of the load. The screws used each have an ultimate strength of about 70 tons, but were not loaded with more than 20 tons.

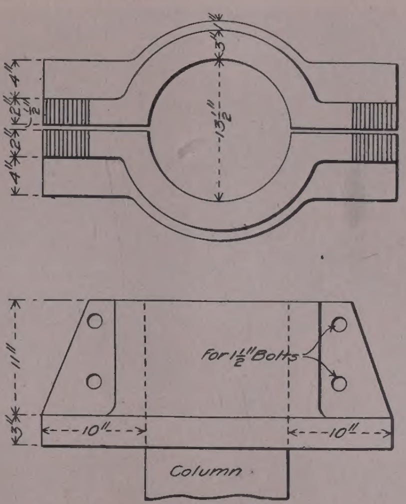
When the two sets of shoring for a column had been set, the load on the latter was transferred from the masonry footing of the column to it by slightly raising the screws under the ends of the I-beams carrying the clamp on the column. The bearing plate at the foot of the column was then removed and the masonry footing cut out. The excavation for the footing of the column of the new building was then carried down to rock directly under the base of the old column. The excavated material was brought to the surface in buckets with a specially designed electric hoist built by the Monagan Engineering Works, and then hauled in wheelbarrows to a chute leading down to the subway tunnel. The first 45 ft. of the circular excavation for each footing was sheeted with 3-ft. lengths of 3-in. tongue and grooved sheeting, 6 in. wide. To this depth this sheeting was braced at every 3 ft. level with a 12x12-in. waling piece in each quadrant of the circular cross-section of the sheeted excavation, the two diametrically opposite walings being braced against each other across the excavation with two screws on 8x8-in. drums. These drums were placed at the ends of the walings, which were the shape of a segment of a circle, so that sufficient space was left between them for the hoist buckets to be raised and lowered. Below the 45-ft. level the footing excavations were braced with 2-in. tongue and grooved sheeting held in place by iron bands. The concrete was mixed in an electrically operated Smith mixer, which was set so the concrete was discharged directly into place in the excavation through a sheet-iron tube. This method of dumping the concrete as far as 100 ft. through these tubes is frequently followed with satisfactory results in building these footings in Chicago.

The soil on which the old footings were built is more or less yielding, and in order to absolutely insure the stability of the old building during the construction of the new footings the total bearing area of the two sets of shoring carrying each column was made approximately 4 times the bearing area of the original column footings. Even with this factor of safety the shorings would sink somewhat as the soil under them became compacted. The columns were held to the proper height when such sinking occurred by raising the screws under each end of the I-beams. After each new footing had been completed at 45 ft. below grade, two box girders were placed across the excavation still remaining open above it, and under the base of the old column over it. The ends of these box girders were placed on cribbing built on the clay. In order to compact the clay under these cribs, screws on drums were placed between the tops of the girders and the lower flanges of the I-beams carrying the column. Part of the load on the latter was then transferred temporarily to the girders. When the clay under the cribbing carrying the girders had been compacted by this loading, the column was raised slightly and its stool slipped between its base and the top of the box girders. Part of the load was then transferred permanently to these girders through the column stool. The columns will be supported on the shoring until the building is wrecked down to the first floor. The heavy sheeting and bracing in the open excavations above the tops of the completed footings for the new building prevents any displacement of the clay under the shoring.


Reinforced Column under Eight-Story Building


Shored Column under Eight-Story Building.

The footings of the columns of the old building under which no excavations for new footings had to be made were exposed 3 to 5 ft. when the old basement floor level was lowered. The excavation of this heavy wet clay from around these footings resulted in several of the latter being cracked transversely, or longitudinally under the column which each of them carried. Shoring was built around each of these footings to relieve any possibility of their failure, and part of the load was transferred to this shoring. One of these reinforced columns and footings is shown in the foreground of one of the photographs of the suspended columns. If the footing had cracked transversely and was bent down at the center, as most of them were, a 12x12-in. timber was placed on the clay on each side of it; then a transverse 12x12-in. timber was placed across each end. The transverse end timbers thus had bearing on the longitudinal timbers on the sides and on the ends of the footings. A cribbing was built up on these four 12x12-in. timbers. The load was partially transferred to this cribbing by two nests of screws, 14 to 18 in a nest, that carried steel rails on which one of the regular column clamps was set. If the footing had cracked longitudinally the same general method of loading was followed, but the arrangement of the bottom 12x12-in. timbers was reversed, the two lower 12x12-in. timbers being placed on the clay along the ends of the footing.



Clamps for Columns.

The old 9-story building on the corner adjoining the site of the 8-story building has only a single basement, the floor level of which is 14 ft. below the street grade. This building is a steel-cage structure, but its outside walls are of granite masonry and are largely carried, independently of the steel frame, on heavy brick piers in the basement of the building. These piers are built around the outside columns of the steel frame. The piers and those columns were carried by spread footings on the clay just below the basement floor. The loads on these footings vary from 550 to 900 tons. The clay on which the footings are built will be confined along the side of the 3 basements under the new building on the old 8-story building site by only a retaining wall 45 ft. high, when the new 12-story building is erected. For that reason the spread footings of the piers and columns along that side of the 9-story building have been removed and are being replaced by circular concrete footings carried down to rock in the same manner that was followed in making the footings for the columns of the new building. This work has also been done without disturbing business in any way in the 9-story building.

A corner and 5 intermediate piers had to be shored up and new footings built under them. The corner pier has a load of 900 tons on it, not only carrying the corner of the building, but also one end of a wide 2-story arched doorway on each side of the corner. The pier was 10 x 12 ft. in plan and was built of brick. It surrounded a heavy steel column of the frame work of the building. The pier and the column rested directly on a layer of 12-in. I-beams imbedded in concrete. Under this layer of I-beams was a second layer placed in the opposite section, and beneath that a third layer placed in the same direction as the first. The length of the beams was increased in each layer, the imbedding concrete being 22 ft. square at the base and 2 ft. thick. The load on the pier and column had to be transferred from this footing to shoring built up on and around the latter, in order that an excavation 10 ft. in diameter could be made for the new footing and carried down to rock directly under the pier. This work had to be done in a basement 12 ft. high and without any interference with business in the building overhead.

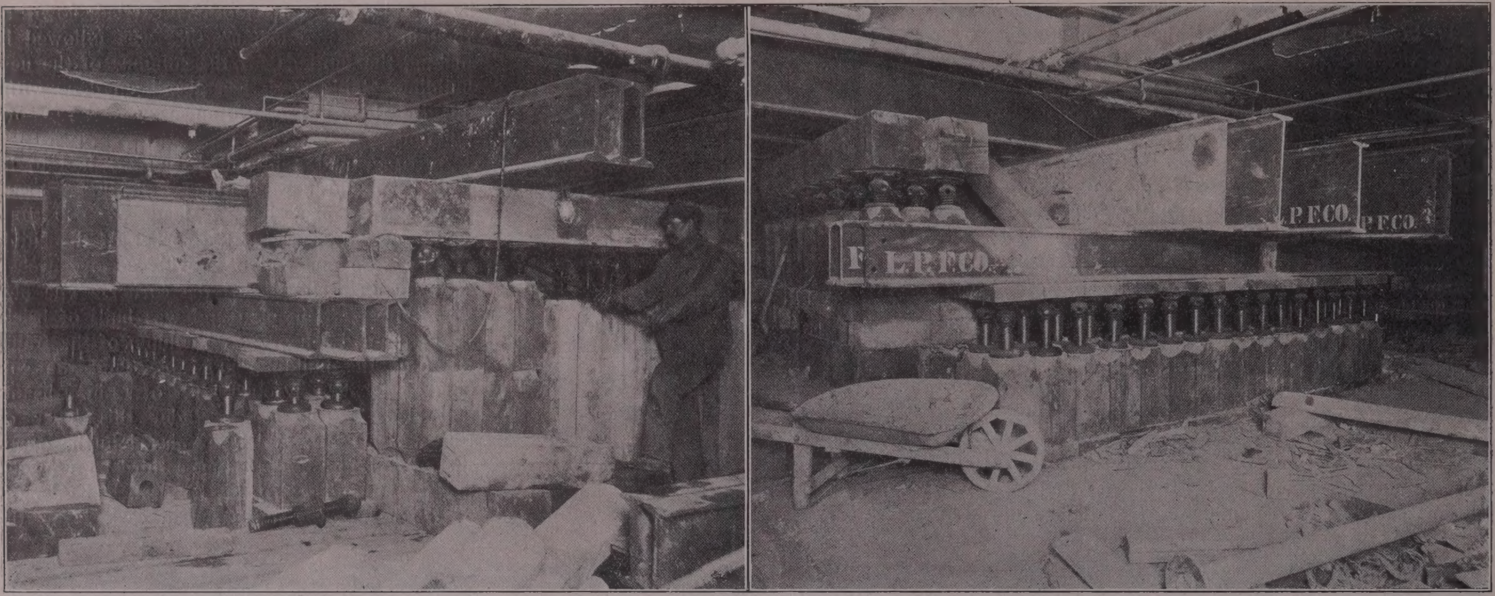
The clay around the concrete of the spread footing was excavated for a width of 3 to 5 ft. to about 1 ft. below the top of the footing. Two 12x12-in. timbers, 26 ft. long, were then placed in the excavation at each of two sides of the footing. Between the ends of these timbers, 12x12-in. timbers were placed in the excavation on each of the other two sides of the footing. A base 26 ft. square was thus formed by the footing and the timbers around its sides. On this base was built the shoring carrying the pier while the excavation for the new footing was made and the concrete of the latter placed.

The shoring under the pier is quite clearly shown in two of the accompanying illustrations. A space about 11 x 12 ft. in plan at the center of the base formed by the concrete of the spread footing and the timbers around it had to be left free of shoring in order that the new circular footing could be built under the pier. Three tiers of 12x12-in. timbers were built up on the 26-ft. base, leaving the central space over the concrete. The timbers in each tier were placed transversely to those in the tier next below. The timbers that would have extended across the central space were cut off at the edge of the latter.

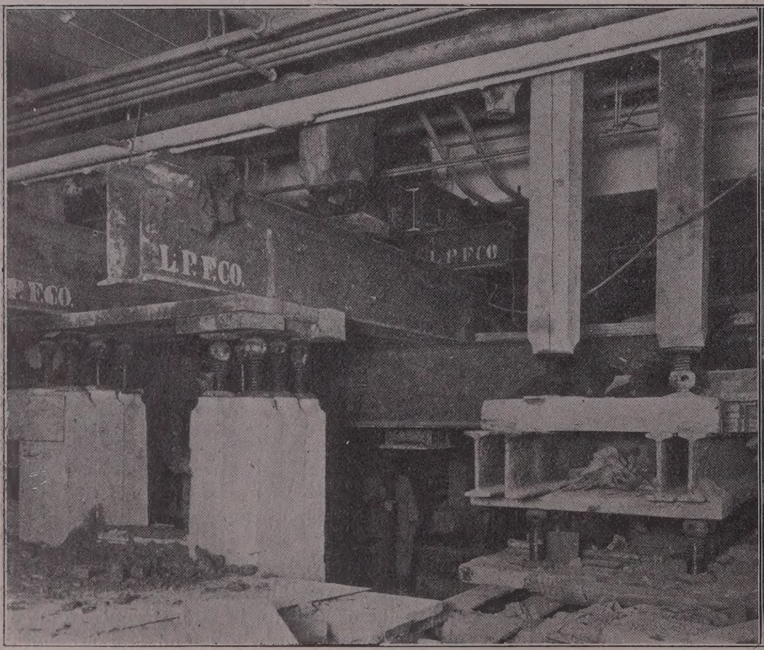
Preparations were then made to transfer the load on the pier to the shoring. The brickwork of the 10x12-ft. pier was cut away on the opposite sides of the latter until a heavy 15-in. I-beam, 26 ft. long, could be slipped into the hole thus made. This cutting away of the brick work and slipping in the I-beams was continued until ten of the 15-in. beams had been put under the pier, each beam being keyed in tightly with wooden wedges between its upper flange and the brickwork. Three of these beams are shown directly over the workman's head in one of the photographs of the shoring for this pier. The outer one of these 3 is along one edge of the pier. At about the longitudinal center line of pier were 4 more beams close together. The other 3 beams were at the other side of the pier. The final method of shoring these 10 I-beams, which carried directly the load of the pier, is also shown in the illustrations. This method is practically the same that was followed throughout the work. The rows of jack-screws on which the man is at work were, however, finally moved out toward the ends of the beams to secure more room around the pier.

These rows of screws and drums, and those against which a shovel is standing in the other illustration of the shoring of this pier carried the ends of the ten 15-in. I-beams. As the brickwork was cut out of the pier and the 15-in. I-beams placed in the holes thus made the load on the pier was slowly transferred to these beams. The load on these beams was partially carried by eight 24-in. I-beams, 26 ft. long, placed transversely immediately under them. These transverse beams were also slipped into place as fast as the brickwork of the pier was cut out. They were carried near each end by four heavy 12-in. I-beams placed transversely to them. Each set of four of these 12-in. beams stood on two rows of screws and drums placed on the cribbing of timbers on the 26-ft. base.

When this shoring was all in place and the load on the pier had been transferred to it, the brickwork of the pier was removed down to the concrete of the footing. The top tier of I-beams in the latter was then removed. The I-beams in the other two tiers extended into the concrete under the timbers around the central space in the shoring. As a hole 10 ft. in diameter had to be cut through the old footing under this space, the concrete between the I-beams and the portion of the two tiers of beams over the site of this hole were cut out. The 10-ft. circular excavation for the new footing was then made to rock, about 100 ft. below the basement floor, directly under the suspended pier one of the same hoists that were used in the excavations for the other footings being used in this one. The new concrete footing was then built up to the basement floor level and after the concrete had set sufficiently the load of the pier was transferred to it. Screws on drums were placed



Two Views of the Shoring for a Pier Carrying Nine Hundred Tons.



Shoring Intermediate Column, Nine-Story Building.

Corner Pier of the Nine-Story Building.

vertically between the top of the concrete footing and the bottom of the pier and the load transformed to the former by raising the screws slightly. Then the shoe of the column in the pier was placed on the footing and the brickwork of pier rebuilt down to the latter.

The loads on the intermediate columns along the side of the 9-story building vary from 420 to 650 tons. These loads were transferred from the columns to shoring and a new footing built under each column in much the same manner that was followed in building a footing under the corner pier. A very heavy cast-iron clamp, similar to the clamps used in holding up the columns of the 8-story building, was attached to each of these columns. The latter are built up of structural steel sections, and are box girders in cross-section with a flange at each end. Four 2x2-in. holes were cut in the same plane at the edges of these two flanges, a hole being made in each flange on both sides of the web of the column. A 2x2-in. tool-steel bar was placed horizontally and parallel to the web of the column in the pair of holes on each side of the latter. These two bars extended into holes in the clamp and secured a grip for the latter on the column. The clamp was carried by 4 extra heavy I-beams, two on each side of the column. These beams rested on six 20-in. beams transverse to them, three on each side of the column. Between the pair of heavy I-beams under the clamp and on each side of the column were placed three 2x16-in. tool-steel plates, one on top of the other. These plates also rested on the 20-in. beams and had a bearing on an angle riveted on the flange of the second section, thus carrying part of the load on the clamp. These 20-in. beams spanned the site of the excavation for the new footing and were carried at each end by four extra heavy 10-in. I-beams transverse to them. Each set of four 10-in. beams under the ends of the 20-in. beams was carried by two rows of screws set on screw plank built up on shoring over and around the old spread footing of the column.

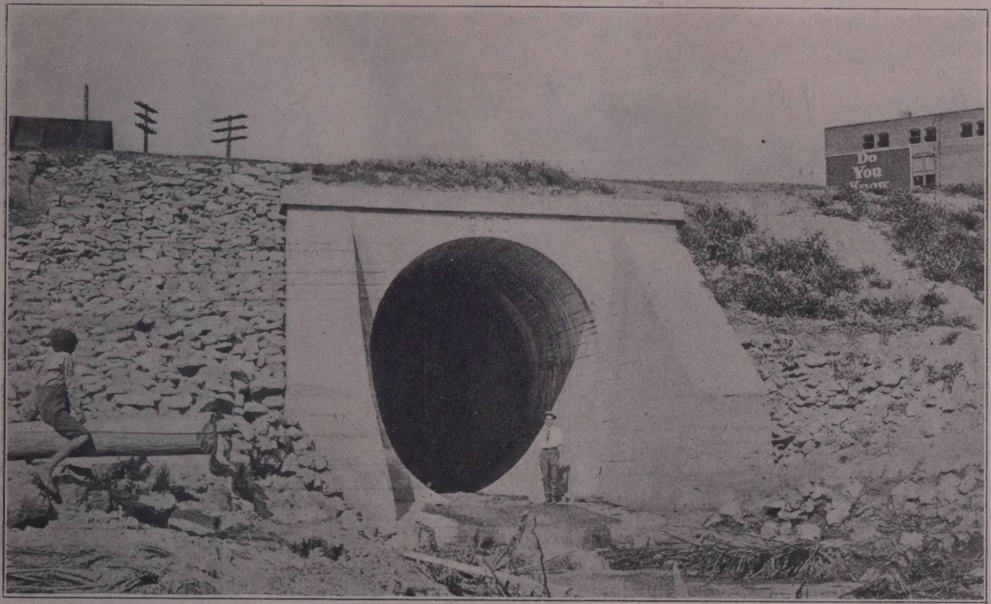
The load on the first floor girders carried by each column was transferred to a separate system of shoring, which was carried by 4 I-beams, 2 on each side of column. These beams were transverse to and above those carrying the column. Each pair of them was carried by 6 screws and drums set on the shoring just outside of the excavation for the new footing. An accompanying illustration shows the shoring for an intermediate column of the 9-story building. At the right in this illustration may be seen the two rows of screws and the four 10-in. beams carry one end of the 20-in. beams on which the column clamp stood. The workman near the center of the illustration is standing over the excavation, 100 ft. deep, which has been made for the new footing; directly over him is the base of the suspended column. The two sets of 6 screws and drums and the 4 beams which they carry are just to the left of the center of the picture, and are a part of the shoring under the first floor girders.

All of the columns of the 8-story building and the 6 piers and columns of the 9-story building were on shoring at the same time. As an evidence of how carefully the buildings were maintained without settlement during this work it may be noted that not a single one of the very large plate glass show windows in either building was broken. The difficulty of placing the shoring was greatly increased by the necessity of maintaining the electric-wiring ducts, the pipes of gas, water, pneumatic-tube, automatic sprinkler, and other service systems which were largely exposed on the ceiling of the basement of the 8-story building.

The work on the shoring of the old buildings and on the footings for the new building was started Jan. 28 last. Since then three 8-hr. shifts have been working continuously. Wrecking of the 8-story building was started April 15. The occupancy of the old building was, therefore, continued for nearly three months after the construction of the new building had been started. The methods used in shoring the old building and the service afforded in the subway for removing the excavated materials, made possible the occupancy of this valuable merchandising space for a so much longer time than would have been possible under the usual method of wrecking old buildings on the site before the construction of the buildings which replace them has been started.

The shoring work required under the two buildings was planned and carried out by the L. P. Friestedt Co., building raising and moving engineers, of Chicago. Wells Bros. Co., of Chicago, was the general contractor for the substructure work on two buildings.

THE PORT OF ANTWERP is to be greatly improved, the Belgian Parliament having appropriated about $40,000,000 for the purpose.



Mouth of 13 by 15 Foot Blacksnake Creek Sewer at St. Joseph, Mo.

Concrete and Concrete Block Sewers in St. Joseph, Mo.

St. Joseph, Mo., is in the northwest corner of the State and covers an area of 9.75 square miles, with a 3.5-mile frontage on the east bank of the Missouri River. The central business portion of the city is built on comparatively level ground, but back of and to the north of this district is a series of steep bluffs, which are cut through by narrow valleys leading to the river. The storm water run-off from these bluffs is heavy and follows suddenly after a rainfall. The sewerage system of St. Joseph is built to carry the combined domestic and storm-water flow, which is discharged into the Missouri River. The original sewer system was begun 25 years ago and from that time until 1902 the main sewers were with very few exceptions built entirely of brick; the few exceptions are those built of native limestone. The later, or district sewers, which include all sizes from 8 to 30 in. in diameter, have been built of vitrified sewer pipe. The main sewers are paid for by the city out of the general fund raised by taxation and have been extended each year as much as the funds available for this purpose, would allow. The lateral or district sewers are paid for by the property owners.

The main sewers were mostly built up the valleys between the bluffs and served the developed portion of the city. The recent rapid growth and extension inland, of the residential districts has required the extension of the main sewers and the building of lateral systems for the recently developed areas. The requirements for the extension of the main sewers being greatly in excess of the available funds the city issued bonds for this special purpose; the amount realized from the sale of these bonds being $225,500. This amount was apportioned and appropriated for the extension of 6 of the main sewers which would serve the greatest extent of the newly developed area. Work on two of the extensions has already been completed and on three others is nearing completion, while on the remaining one, the work has just fairly begun. The capacity of the old main sewers, with two or perhaps three, exceptions, is thought to be entirely adequate to carry any flow that will ever reach them, even after most of the areas tributary to the various mains have been entirely built up and paved. For that reason no new main sewers have been built at this time in the area covered by the city proper.

The extensions have all been built of plain concrete, reinforced concrete or concrete blocks. The larger reinforced-concrete sewers were built according to the system controlled by Mr. W. C. Parmley, and the concrete block sewers were built according to designs also controlled by Mr. Parmley. The largest sewer to which an extension has been built is known as the Blacksnake Creek sewer. This sewer has a somewhat elliptical or oval shape, and at its mouth has a diameter of 17.5 ft. vertical by 14.5 ft. horizontal. In 1903 this sewer was extended for a distance of 114 ft. toward the river, under the tracks of the Chicago, Burlington & Quincy and the Chicago Great Western Railways in order that the old creek bed might be filled and the bridges then in use abandoned. This extension was built of concrete. The Blacksnake Creek sewer extends from the Missouri River up the valley of a stream called Blacksnake Creek. This creek has a drainage area of about 8 square miles of rough country between two rows of bluffs, one to two miles apart. Although the storm-water flow from this area is heavy, the stream during certain seasons is nearly dry, and the domestic sewage that reached the creek above the end of the old sewer produced unsanitary conditions during such seasons.

This sewer for a distance of 5,808 ft. from the concrete extension at the river was built entirely of brick, and at its upper end had been reduced to a diameter of 15 ft. vertical by 13 ft. horizontal. The objects of extending this sewer were first, to provide an outlet for an 8-ft. and a 3-ft. main sewer from each of two drainage districts tributary to the stream, and second, to fulfil an agreement between the city and the Chicago Great Western Ry. The extension was also built up the valley of the stream, but avoids the bed of the latter as much as possible in order to obtain a more solid foundation. The general direction of the old stream bed is more or less closely paralleled by the yards and tracks of the Chicago Great Western Ry., and the diversion of the stream into the sewer will permit the bed of the stream to be filled in and utilized by that railroad. The extension of this sewer was built entirely of plain concrete without any reinforcement whatever, and is 2,083.26 ft. in length. The first 632.45 ft. in length, which extended the sewer beyond the entrance of the 8-ft. sewer, has the same cross-section as the old sewer. The remaining 1,451.81 ft. has a circular section 12 ft. in diameter.

The extension was made without any unusual construction difficulties. The fall of the stream is great enough to avoid any necessity of much deep cutting for the sewer. The trench was made through various kinds of clay and sandy soil in the most of which the trench sides stood well. A Lidgerwood cableway was set up longitudinally over the trench and handled buckets between the excavation in the trench and the back-filling over the completed sewer. The sewer was built in 14-ft. lengths. The concrete was mixed in the proportions of 1 of Iola Portland cement, 2 of Missouri River sand and 4 of broken limestone. The broken stone was the crusher-run, with the dust screened out and the maximum-sized pieces not to exceed those which would pass a screen with a 1-in. mesh. A Campbell mixer on a truck was set up along the trench, and concrete was shoveled from a dumping board through a chute into place in the trench.

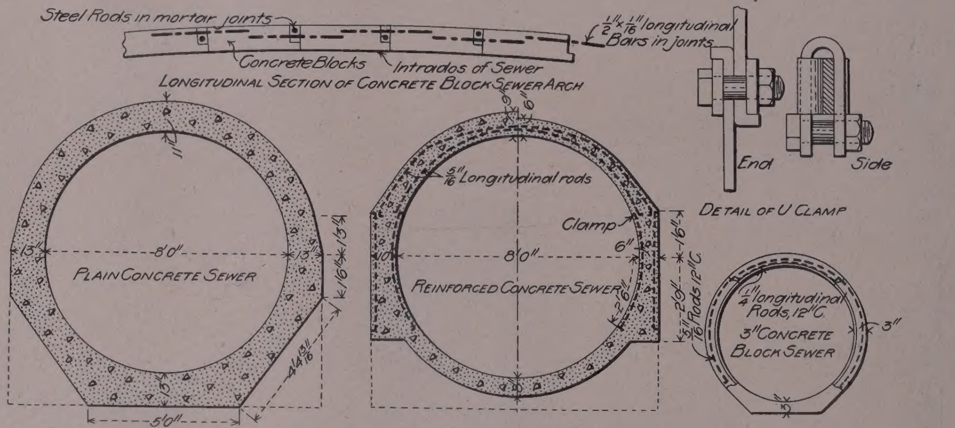
The old 8-ft. sewer mentioned as having been connected with the Blacksnake sewer is known as the Grand Ave. sewer. It is 1,210 ft. in length and was built entirely of brick. This 8-ft. sewer has already been extended for a distance of 1,114.5 ft., and follows the general direction of the valley of the east fork of Blacksnake Creek. It has been constructed of reinforced concrete and is designed in accordance with the Parmley system. The general section required 0.63 of a cubic yard of concrete and 17.1 lb. of steel per linear foot, but in addition to this, the use of extra concrete was found necessary in many places for bench walls and more substantial footings.

The steel reinforcement consists of transverse bars and longitudinal rods, placed as shown in the cross-section. The transverse bars are 3/16 x ½ in. in section. The bars near the intrados of the sewer arch are placed 2 ft. on centers; those near the extrados are also 2 ft. on centers. The longitudinal rods are 3/16 in. in diameter and are interlaced between the transverse bars.

The sewer barrel is first built up to the springing line of the arch; pieces of the transverse bars long enough to extend 1 ft. 6 in. above that line being placed in the haunches of the arch. After the forms and lagging have been placed for the upper half of the sewer the arch bars are carefully placed and fastened to the side bars with clamps, the detail of which is shown in one of the illustrations. The longitudinal rods are next wired to the arch bars and the work is then ready to receive the concrete, which is mixed very wet in order to permit it to flow completely under and around the steel bars.

A 3-ft. sewer, 902 ft. long, built of Parmley concrete blocks connects with this 8-ft. sewer. The cross-section of this 3-ft. sewer is shown in one of the accompanying illustrations. The sewer barrel is built in four sections, an invert, two side sections and a closing section at the top. These sections are made 1 ft. wide and are cast in specially designed forms. One side of each of the sections, except the invert section, is cast with a projection ¾ in. wide and 1 in. thick, which has its inner face flush with the inner face of the sewer barrel. The sewer barrel is built in 1-ft. lengths, the projections on one side of one set of 4 sections abutting against the straight side of the adjoining set. A 1/16 x ½-in. bar is warped around the upper 3 of each set of 4 sections, as shown in the cross-section, in the outside groove formed in the joint between the two sets of sections by the projections on one set of blocks. The remaining space in this groove is then filled with cement grout.

Another of the main sewers known as the Mitchell Ave. sewer has a diameter at the river of 14 ft. vertical by 12 ft. horizontal, and was built entirely of brick for a distance of 8,175 ft. Where the brick sewer ends, the size had been reduced to a diameter of 10 ft. vertical by 8.5 ft. horizontal. This sewer has been extended 1,752 ft. by the construction of a plain concrete sewer circular in section and 9 ft. in diameter. From the end of this 9-ft. sewer, there are two branches, one an 8-ft. plain concrete sewer, which has already been built for a distance of 650 ft., and the other a 6-ft. plain concrete sewer of which 700 ft. has been built. Work is now in progress on both of these branches, and it is expected that they will be completed within the next 60 or 90 days.



Types of Sewers at St. Joseph, Mo.

A cross-section of the 8-ft. sewer is shown in one of the accompanying illustrations in which the full lines show the general, or regular, section, and the dotted lines, the section used under special conditions. The general section required 1.16 cu. yd. of concrete per linear foot as compared with 0.63 of a cu. yd. per linear foot required in the reinforced-concrete sewer of the same section. The contract price for the 8-ft. sewer built of plain concrete complete, without the cost of excavation or back-fill, was $6.90 per linear foot on the Mitchell Ave. sewer. The contract price for the 8-ft. reinforced concrete sewer, complete without cost of excavation or back-fill was $6.30 per linear foot on the Grand Ave. sewer. The comparatively low price of concrete materials in St. Joseph and the extra cost of placing the steel and concrete in the reinforced sections makes the actual cost of plain and reinforced-concrete sections about the same, with the difference, if any, in favor of the plain concrete, according to Mr. William H. Floyd, Jr., city engineer of St. Joseph.

Included in the work to be done with the $255,500 appropriation is the provision for the partial construction of a system of sewers for a newly developed territory around the packing house district in the southern part of the city. This district is largely at the foot of high bluffs, ½ to 1 mile from the river. Between these bluffs and the river is a low, flat bottom that is just above extreme high water in the river. The heavy storm-water run-off from these bluffs frequently floods the land around the packing houses and stock yards in the low area before it reaches the river. In order to carry this flood flow immediately to the river and to provide an outlet for a sewerage system for the district near the bluffs, an 8-ft. reinforced-concrete sewer is being built across this area. This sewer is 3,900 ft. long, and as it is built according to the Parmley design it is similar in construction to the Grand Ave. sewer. A system of 3½ to 5-ft. sub-mains, of either concrete blocks, or plain concrete will be constructed in connection with this main outfall.

The 8-ft. sewer after crossing the low, flat bottom will have to pass under 19 railroad tracks. Where it passes under these tracks, a special form of section will be used which will require 1.21 cu. yd. concrete and 17.3 lb. of steel per linear foot; the thickness of the concrete at the crown of the arch being 9 in.; at the springing line of the arch and at the invert, 10 in.

The extensions of the main sewers and the new sewers that have been built were designed and are being constructed under the direction of Mr. William H. Floyd, Jr., city engineer, of St. Joseph.

The German Cartel, which has developed until it has a very important place in the industrial world of the empire, is an association of kindred firms for the purpose of maintaining prices, and in which the firm does not lose its identity, but is controlled, nevertheless, as to output and selling price by a central committee. The cartels reach the very considerable number of 385 distinct associations, embraced in 16 categories. The coal industry has 17 cartels, including 6 associations of buyers; the iron industry comprises 62 cartels; metal (other than iron), 11; the chemical industries, including salts, acids, alkalies, colors, glues, artificial manures, explosives and soaps, have 46; textile industries, 31; leather industries, 2; caoutchouc industries, 3; wood industries, 5; paper industries, including printing paper, wall paper, and cellulose, 6; glass, with the plate, mirror, and bottle industries, 10; brick cartels numbering 138 buying associations; stone and earth industries, such as cement, lime, asphalt, chalk and gypsum, have 27; porcelain and pottery, 4; food and beer industries have 17; electrotechnical industries, 2; in addition to 7 scattering, including a syndicate for steam turbines, a syndicate for asbestos, a wagon-building and a linseed-oil union.

Economy of Steel Sheet Piling for Coffer Dams for Bridge Piers.

By Julian Griggs, M. Am. Soc. C. E.

There was published in The Engineering Record on April 21 an account of the use of steel sheet piles for cofferdams in the construction, on a changed alignment, of a new bridge over Paint Creek near Chillicothe, Ohio, for the Norfolk & Western Railway Co. The writer was interested in the improved method described for the reason that he had charge of the construction of the substructure on the old bridge as chief engineer for the receiver of the Scioto Valley Railway Co. in the autumn of 1885, and is for that reason able to make a comparison of cost by the old and the new methods. The earlier work was done by contract at very reasonable figures and a statement of the cost of the old cofferdam as compared with the new may be of interest to others of your readers. It will, however, be well to describe briefly the general location and the conditions affecting the work.

The first railway bridge at this point was built in 1875. It was a wooden Howe truss of three spans of 140 ft. each on pile piers and abutments. Two thousand feet below the bridge site a mill dam about 8 ft. high backed the water into a pool extending upstream three-fourths of a mile. Two hundred and fifty feet above this bridge the Ohio & Erie canal is carried over the stream by a wooden aqueduct of two spans of 88 ft. each. The valley is alluvial, broad and well cultivated, with its flood plain about 5 ft. above the crest of the dam, but the flow of the stream is confined to its channel by the embankments of the canal and railway, although backwater from the creek or the Scioto River covers the flood plain in time of freshet. Paint Creek is a rapid stream and usually passes its main discharge before the crest of a Scioto River flood arrives. In February, 1884, heavy general rains swelled the creek to an unusual volume. The aqueduct was swept from its abutments and against the railway bridge and both structures were destroyed. A temporary pile trestle with 16-ft. spans was immediately constructed, and traffic on the railway resumed after a few days' interruption.

Extension of 13 by 15-Foot Blacksnake Creek Sewer, St. Joseph, Mo.

The trestle above noted was maintained until the spring of 1886, but masonry for an iron bridge was built in the late fall and the winter of 1885-6, under a contract executed Oct. 10, 1885, by Robert Wynn and Leonard Wishon, of Portsmouth, O., both of whom are now dead. The base of rail on the old bridge was 15.7 ft. above low water, as determined by the crest of the dam above noted, and this grade, in the plans for the new structure, was raised 2 ft. for additional head room. The spans for this bridge were reduced to three of 120 ft. from center to center of piers, on a skew of 67 deg. The water was about 5 ft. deep at the abutments and 7 ft. at the piers. It will thus be seen that the headroom for operating a pile driver under the trestle was limited. The piles were driven into the bed of the creek an average of 15 ft., cut off 8 ft. below the surface of low water, and covered with a grillage of timber as a foundation for the ashlar sandstone bridge masonry.

The cofferdams were four in number; those for the abutments needed but three sides, the bank of the stream forming the fourth. The coffers for the piers were rectangular in place, about 22x45 ft. inside, 35x58 ft. outside dimensions.

Short piles were used, 26 to 36 in number for each structure, spaced about 8 ft. apart, with 3-in. waling and vertical 2-in. plank sheeting, cross-bolted at intervals and filled with earth.

Laborers' wages were $1.25 for 10 hours and the unit prices obtaining were for material in place as follows: Piles, 30 cents per linear foot; cofferdam and foundation timber, $24 per M. ft., B.M.; bolts, 5 cents per pound; riprap, $1 per cubic yard; dry earth excavation, 20 cents; wet earth excavation, 50 cents; cofferdam filling, 20 cents, and bridge masonry, $7 per cubic yard.

The final quantities in detail and the contract payments for the four cofferdams were as follows:

35,225 ft. B. M. of timber in cofferdam, at $24..	$845.40
2,570 lin. ft. piles in place in coffer dam, at 30 cts.	771.00
150 pounds of iron bolts, at 5 cts................	7.50
930 cu. yds. earth filling in coffer dam, at 20 cts..	186.00
Total	$1809.90

The contract cost of the several coffers differed materially. The payment for the cofferdam at the north abutment was $291.28, at the north pier $587.90, at the south pier $549.54, at the south abutment $381.18, an average of $452.50.

In carrying out this work some curious things were noticed. A considerable accumulation of fine silt had collected on the bottom of the stream, due to the effect of the mill dam in checking the current, and beneath the silt, as has been stated, the gravel was limestone and very coarse, up to stones 8 in. in diameter, well worn but rather flat, with little or no fine material; it passed water freely and it was found impossible, at least at any reasonable expense, to lower the surface by pumps in the cofferdams more than about 8 ft. That this was not due to leakage into the cofferdam enclosures from the stream was shown in pumping out for the south abutment, last built, which lowered the water in each of the other three coffers a nearly equal amount; also by the fact that when pumping was discontinued, the north coffer had at one point a low crest, over which a small stream continuously flowed from the surface of the creek for several months, without ever raising the water within the coffer to the level of the creek outside, the constant difference in level being about 2 ft. This water continued to flow away through the coarse gravel above mentioned and presumably entered the stream again at some point below the mill dam 2,000 ft. away, thus clearly showing a fact not always appreciated that silt bearing streams are for the most part water-tight against loss of volume by outward percolation.

From conversation with Mr. L. E. Sturm, the contractor for the work by the new method, I learn that in addition to the cost of placing the first and second cofferdams of $70.50 and $117.50, respectively, there should be added the cost of drawing the steel sheet piling at one-half the expense of placing, or $94 for the two, averaging $140.75 per structure for placing and removing. The steel sheet piles cost $40 per short ton at Pittsburg and weighed 35 lb. per linear foot. There were required 152 straight pieces 16 ft. long, also four corner pieces for which there was an additional charge of $8.96 for bending the web to an angle of 90 deg. Allowing then $1.50 per ton for freight on 43.68 tons to the point of using, the total cost of the material was $1,821.68. If we divide this amount by five for the number of times the piles have been used, we have $364.34 per structure for material plus $140.75 for placing and removing, or a total of $505.09 per structure, as against the contract cost of $452.50 for the work by the old method in 1885. If, however, we recognize the increase in cost of labor and material and assume as fair present unit prices $24 per M. feet B.M., 50 cents per linear foot for piles, 5 cents per pound for iron and 50 cents per cubic yard for earth puddle in coffers, the present cost of the cofferdams by the old method would have been $638.22. This gives an economy in favor of the new method of $132.13 per structure.

This favorable showing would be still further increased by making a proper allowance for salvage on the steel sheet piles or rather, perhaps, by considering them as a tool and charging off, say, 10 per cent. of the total cost against each job to cover interest and depreciation, as I am informed that notwithstanding the five-fold use of these piles to date they are uninjured and for all practicable purposes as good now as when new, a little battered only on one end by driving, which might have been avoided by using a cast-iron cap weighing 600 lb. and costing $20, furnished if desired by the United States Steel Piling Co.

Boats with Gas Producers and gas engines are described in a paper presented to the Institution of Naval Architects by Mr. J. E. Thornycroft. The system designed by Mr. Emil Capitaine has been installed on several boats for inland waters and one for voyages in the open sea. A vessel of 200 tons engaged in the Rhine traffic has been equipped with the Deutz producers and engines. It is stated to have given satisfaction in its operation.

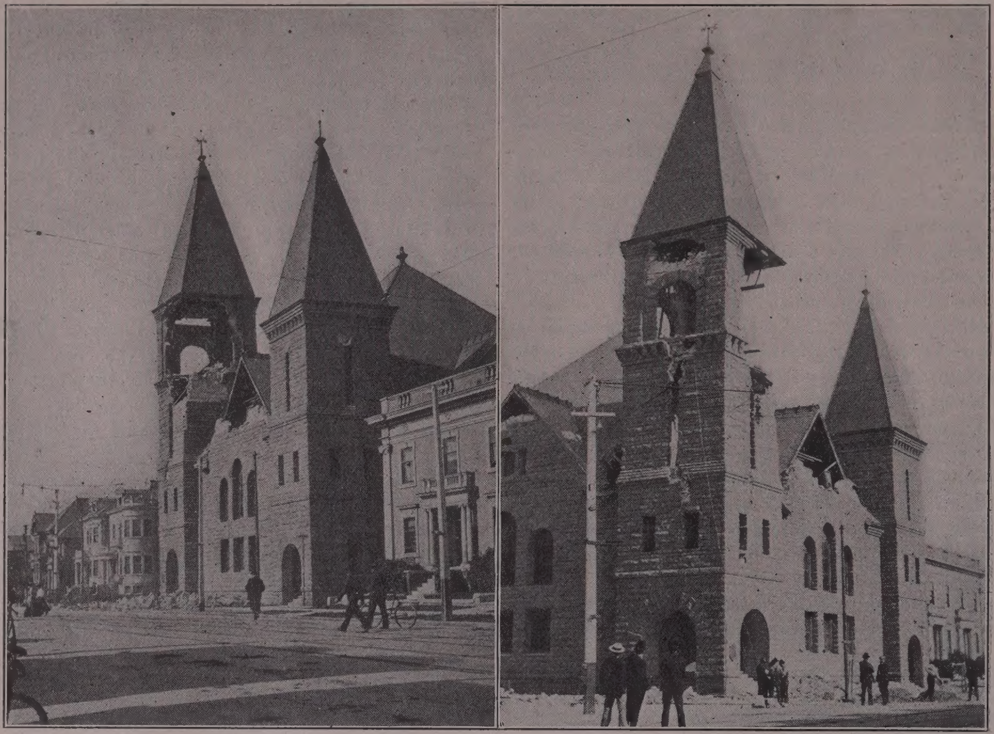
Comments of Californian Engineers on the Earthquake and Fire.

From Mr. Edward M. Boggs, M. Am. Soc. C. E., Chief Civil Engineer, Oakland Traction Consolidated, and San Francisco, Oakland & San Jose Ry.

In reply to your request for information concerning the action of the earthquake which affected this region on the morning of April 18 I regret to say that the strenuous life of the past week has allowed me little opportunity for the thorough study of the subject that I naturally wanted to make. However, a few notes thereon may be of interest although lacking technical detail.

I wish to give great emphasis to the fact that the magnitude of the catastrope should be attributed principally to the conflagration which followed the earthquake. In my opinion fully 95 per cent. of the property loss in San Francisco was due to the fire. The earthquake alone, although severe and causing a heavy loss of life, was not such a world-appalling event. Doubtless there have been numerous others as severe or worse within the limits of the United States since the European settlement.

The destructive action of the tremblor varied greatly according to the geological formation of the immediate locality and the character of the buildings affected. The greatest destruction was to those buildings founded on made ground, especially where a crust of firm ground had been made over mud. Unfortunately, a considerable part of the metropolitan district of San Francisco is so situated. It is a well known fact that the shore line of San Francisco bay some sixty years ago was many blocks inland from the present water front. Hulls of ships were floated in, scuttled and used as buildings. Afterwards these tide-lands were filled in and built upon. It is not surprising, therefore, that great wave-motion was felt in this locality. A subsidence of several feet occurred over a wide area. Well-constructed buildings on pile foundations in this locality stood the shock very well. The double-track cable road on Market street, also founded on piles, maintained good alignment and surface while the horse-car tracks on both sides of the cable-road were heaved up in some places and sunk several feet in others.



Figs. 1 and 2. First Baptist Church, Oakland, Cal.

The safest locations were in the hilly sections where bed rock exists at or near the surface. In these situations scarcely any damage was done. The rock islands in San Francisco bay and the ranges of hills east of the bay were similarly unaffected. At my home in Piedmont, a suburb of Oakland, eight miles from the ferry building in San Francisco and four hundred feet above tidewater, not one cent of damage resulted. Throughout the entire Piedmont district extending along the foot-hills the damage was trifling, while at San Jose, forty-five miles south, and at Santa Rose, fifty miles north, the destruction was very great.

Generally speaking the buildings seriously injured were very old, of unsafe design, improper construction, or of poor materials. This earthquake was the best possible endorsement of the superiority of steel-frame construction for tall buildings. The "skyscrapers" were uninjured structurally by the shock. The damage they suffered was mainly to their finish and ornamental features. None of them collapsed; none contributed to the loss of life. Elevators were operated for hours or days after the shock and until the fire appeared. The instance of the Claus Spreckels building is typical. This is a twenty-one-story building 310 feet high, standing on a lot only 75 feet square. It had long been regarded by laymen as the most dangerous structure in the city in the event of earthquake, but it endured the shock nobly. I did not see it until the fire had swept through it, but it stands to-day an imposing structure. Parts of it are doubtless capable of being occupied after very slight repairs, although the building was far from fireproof and suffered greatly from the fire. The other steel frame buildings have the same satisfactory records.

Of other types of buildings it may be said that their designers seem to have expected the earth to remain always quiescent. A few points concerning them have impressed themselves upon my mind. Massive masonry at great heights above the ground is dangerous, masonry walls at gable ends of high-peaked roofs are especially liable to fall. Heavy copings, parapet walls and enormous chimneys may become mighty engines of destruction. In some instances heavy brick chimneys on school buildings fell upon roofs and like titanic projectiles passed through every floor down to the basement. What a needless slaughter of children would have resulted had the time been later and the schools been filled as usual! It should be made a crime to perpetrate such an architectural blunder.

Many dwellings also were badly injured by their own chimneys crashing through their roofs, or those from adjoining houses rolling down and plunging through windows; and many persons were killed or injured in this manner. Reinforced concrete, sheet metal or even terra cotta are far superior to brick and stone for such a purpose. Most of those killed were in old and

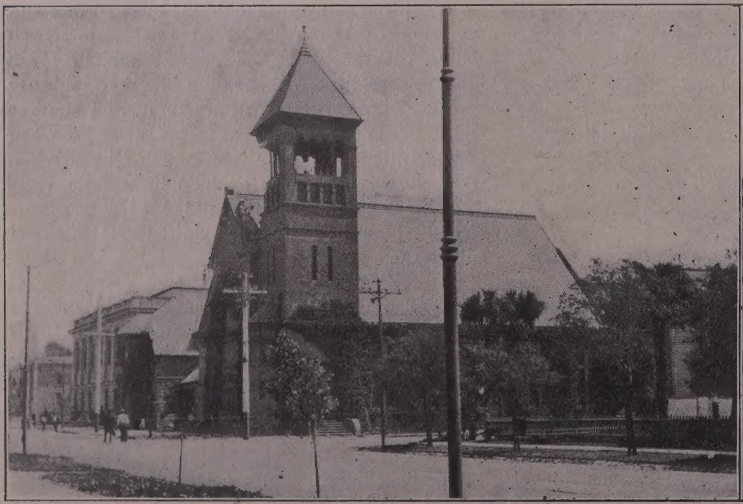


Fig. 3. First Unitarian Church, Oakland, Cal.

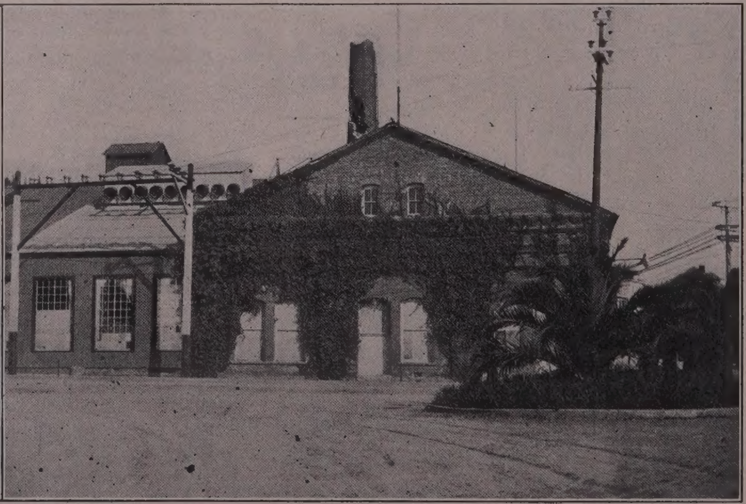


Fig. 4. Piedmont Power Station, Oakland, Cal.

flimsy buildings which collapsed, doubtless in some cases the weaker buildings being pounded to pieces by the heavier ones around them. The calamity occurred at 5:14 a. m.; had it been an hour or so later, when the streets were crowded with people the loss of life would certainly have been many times greater.

I have not seen a single fallen chimney which had been well braced to the roof, although many such were broken across at or near the roof line. Except in fortunate localities the destruction of unbraced chimneys was general and even to-day almost the entire population of the unburned districts are subsisting on uncooked or cold food, or else cooking in their yards or in the streets, while awaiting inspections and repairs of their kitchen chimneys.

Enormous damage was done to stocks of goods by roof-tanks being overturned, breaking through the roofs and flooding the building. Such tanks could readily be braced so as to maintain their upright position.

Masonry walls should be well braced and tied together. If the building can sway as a unit instead of falling apart it will endure a surprising amount of racking. This is exemplified in the cases of many tall but well built church towers. These would seem by reason of their height to be peculiarly subject to destruction, but on the other hand, their smaller diameters gave better facilities for braces and ties and in some instances they stood far better than lower buildings having long walls. But still the damage to church buildings having unnecessary masses of masonry was very extensive.

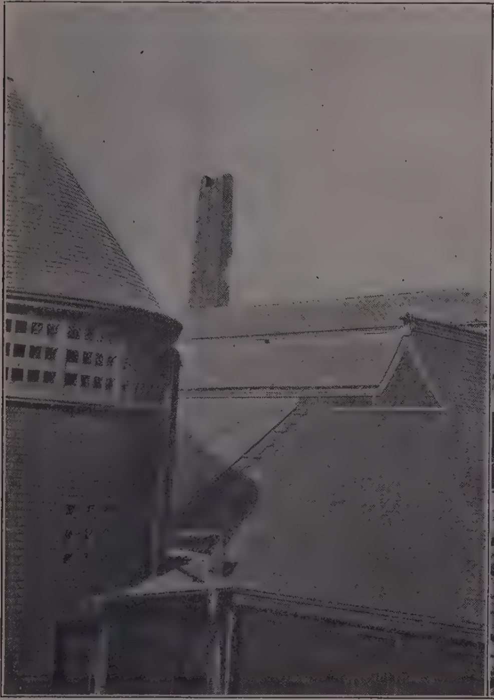


Fig. 5. Stack of Piedmont Station.

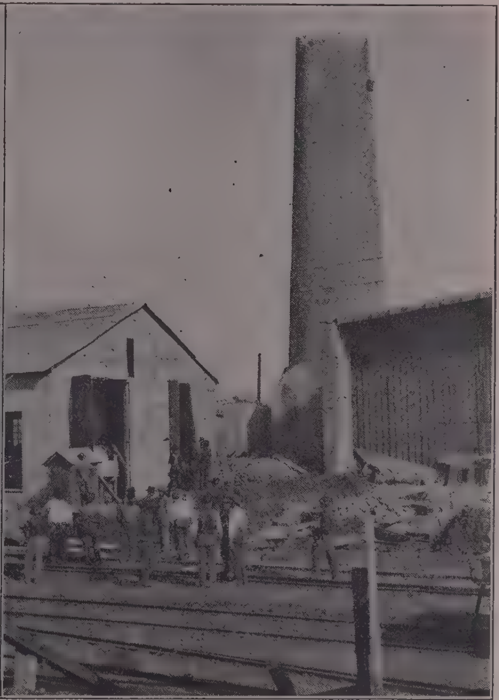


Fig. 6. Stack of Yerba Buena Station.

The Palace Hotel is an example of a building having solid brick walls which withstood the shock well. This was doubtless due to the large number of intersecting partition walls, which were also of solid brick masonry of good quality. On the other hand the Emporium building of about the same height, but having larger rooms and fewer partition walls, was badly wrecked.

A surprising amount of brick masonry which was thrown down was of poor quality, the bricks separating with clean surfaces, showing lack of adhesion of the mortar. Reinforced concrete having greater tensile strength would be incomparably superior to laid-up masonry.

The shock was doubtless as severe on the east side of the bay as in San Francisco. The damage to some buildings was severe, but the total loss was surprisingly light. Nearly all electric railway lines could have been operated continuously had not the management prudently ordered the current kept off the wires until all had been thoroughly inspected. This was done and all electric roads operated within twenty-four hours. On Webster Street, crossing the Alameda marsh, one of the tracks sunk three or four feet. There was here a good deal of end thrust also; a dozen steel rails, 70 lbs. Am. Soc. C. E. pattern, were so badly kinked as to require renewal.

The Key Route pier, a wood pile structure, extending 3¼ miles from the Oakland side out to deep water in the bay, and terminating in a large wood and glass building, was uninjured. But two panes of glass were broken in this building. The heavy brick stack, 126 feet high, at the Yerba Buena power station, lost about one-third of its height from the top. This fell near the base, missing the boilers and engines. The brick stack of the Piedmont power station also lost its upper third. In general tall stacks did not suffer so badly as would have been expected. Were the use of reinforced concrete universal in this class of structures little or no damage would have resulted.

In wooden buildings a great amount of damage to walls as well as contents of rooms can be prevented by liberal diagonal bracing. Tall sideboards, cupboards, book-cases, etc., may well be built in or firmly attached to the walls.

The street railway system of San Francisco suffered far more from fire than from the earthquake. In my opinion this occasion will mark the passing of the underground conduit either for cable or for trolley. It is impotent to resist the ravages of earthquake and fire alike, both of which tend to close the slot; this was done in thousands of places with an unseen amount of damage underground to the conduit and its contents. The overhead trolley roads were but slightly damaged. The speedy rehabilitation of the transportation lines of a great city after disaster from any cause is a matter of extreme importance. This must necessarily be a work of great difficulty with any conduit system. It can be accomplished readily where the overhead trolley is used. Given a sufficient amount of line material on hand and the trolley lines can be put in running order in as many hours as it will take days or weeks or months to restore a conduit line. There had never been a trolley line on Market Street, but to-day they are setting poles for a temporary trolley line in order to open the road as speedily as possible. The labor of doing this among the heaps of debris is colossal, while a few hours work on the overhead construction of the Mission Street electric line has placed it in running order.

It was the breaking of the water mains by the earthquake that permitted the numerous simultaneous fires to escape control and merge into a general conflagration. I have had no opportunity to ascertain the number or location of these breaks. It appears most probable that they occurred principally at points where the mains crossed filled-in ground, or at other places most likely to be disturbed by the shaking. Possibly these danger points can be located in water-works systems generally by advance study, and gates arranged so as to reduce to a minimum the area deprived of protection. The stupendous loss by the fire in San Francisco emphasizes the importance of arranging in the design of a water system for the most perfect control of the water supply. Not only should flow between all portions of the system be available, but means should be provided for segregating the system into the greatest possible number of temporarily independent units, each with its own reservoirs or pumping stations.

Earthquakes are not rare occurrences even in the United States. The next destructive one will probably not harm either Charleston or San Francisco. These localities are reasonably safe for the next generation or two. Any section of the country may be shaken at any moment. The increase of population and its growing cities must render more imminent the danger of disaster on a stupendous scale. Prudence demands that engineers and architects should bear in mind this ever present possibility and design their structures accordingly. The fall of a brick chimney through the roof of the smallest cottage may exterminate a family. How vastly greater may be the destruction by heavier but equally inexcusable features of larger buildings.

As to the future of San Francisco. In my opinion it will rise from its ashes to a more magnificent future than would have been possible without this scourge of fire. It had been her misfortune that she had never been swept by a general conflagration. The loss would have been much less had it come ten years ago, but it is less now than it would have been at any time in the future. It is probable that the plan of the city will be radically changed. The original plan was a huge mistake; to perpetuate it now would be a crime. Streets should be widened, the checker-board arrangement of blocks on the steep hills abolished. Chinatown will be removed from one of the most desirable portions of the city; the way can now be opened to build the city as it ought to be built and I believe it will be done. Its people possess the necessary courage, skill and resources. All that is lacking is the material; that cannot come forward fast enough. There will be an unlimited demand for building supplies for years to come, especially for structural steel and materials for steel-concrete construction.

I enclose a few photographs showing the maximum effects of the earthquake which I have been able to find on the eastern shore of San Francisco Bay.

Views 1 and 2 show the First Baptist Church, at Twenty-first Street and Telegraph Avenue, Oakland. The building has thin walls of brick veneered with stone, the worst possible construction for resisting earthquake. The main portion of the building is practically uninqured except by falling masonry. The ruined tower was pulled down on the second day after the shock.

View 3 shows the First Unitarian Church, Fourteenth and Castro Streets, Oakland. This is a substantial structure of brick and stone. It was not much injured by the shaking except to its single tower. Here the multiple arches occupying so much space on all sides of the tower left but little support. The view shows by the broken line of coping the extent to which the rear gable wall was thrown down. Both front and rear the main auditorium was badly injured by falling masonry. In the left distance is the Carnegie Library, a heavy stone building. Except to interior finish the damage was limited to the destruction of portions of the heavy brick and terra cotta parapet which shows above the cornice. Much of this was thrown down from sides of the building which are not seen in the photograph. The building was structurally uninjured.

Views 4 and 5 show the brick stack of the Piedmont power station, Oakland. This chimney was 136 ft. high; the hole in the side is about mid-height. All above the hole has since been pulled down. This building stands on filled-in salt marsh.

View 6 shows the brick stack of the Yerba Buena power station. It was 126 ft. high; about one-third is gone from the top. Some cracks exist in the remaining portion, but the chimney is in a serviceable condition. It stands on swampy ground near the shore of the bay, but has a very substantial pile foundation. The appearance of confusion in the foreground is due to an extension of the engine and boiler rooms, which has been under way for some time.

Views 7, 8 and 9 are of the electric railway tracks on Webster Street, Alameda. This street is a causeway filled across a tidal marsh—the worst possible formation with respect to stability. The roadway has always been so unstable as to tremble noticeably under any heavily loaded vehicle. The land on both sides has never been filled, so that the roadway has had no lateral support. In View 9 the kinking of the track is due to end pressure buckling the 70-lb. rails. There were several other spots about the same as the one shown.

These views are of places five or six miles from the Ferry Building in San Francisco. They demonstrated the fact that it was the fire and not the earthquake itself which constitutes the record-breaking calamity.

From Mr. Philip E. Harroun, M. Am. Soc. C. E.

I regret that at this time I cannot give you definite information as you request, for since the calamity we have been so busy in matters of organization and relief that we have had no time for anything else. My own observation of the effect of the earthquake embraces that section of San Francisco bounded by the ferries on the east, Market Street on the south, Leavenworth Street on the west and Sacramento Street on the north, together with the business sections of Oakland and Berkeley. It is evident at once that the only type of construction which has successfully withstood the shock is the modern steel frame construction. Buildings of this class are but little injured and in some instances a casual examination fails to show any defect whatever. This is, so far as I have seen, true without exception. With one exception buildings of brick and stone are badly shattered. The exception is the walls of the Palace Hotel, which seem to be practically intact. From what I have seen there is but one type which can successfully withstand both earthquake and fire, and that is the steel frame construction, and I believe that when we are able to make a careful examination into the matter this will be fully confirmed.

From Mr. Stephen E. Kieffer, Assoc. M. Am. Soc. C. E.

My observations have been very general, due to the fact that at the time of my visit to the ruins the fire was still in progress and martial law so rigidly enforced that the only guarantee of one's life was to keep strictly to the streets, even though the heat of the ruins had permitted a close inspection.

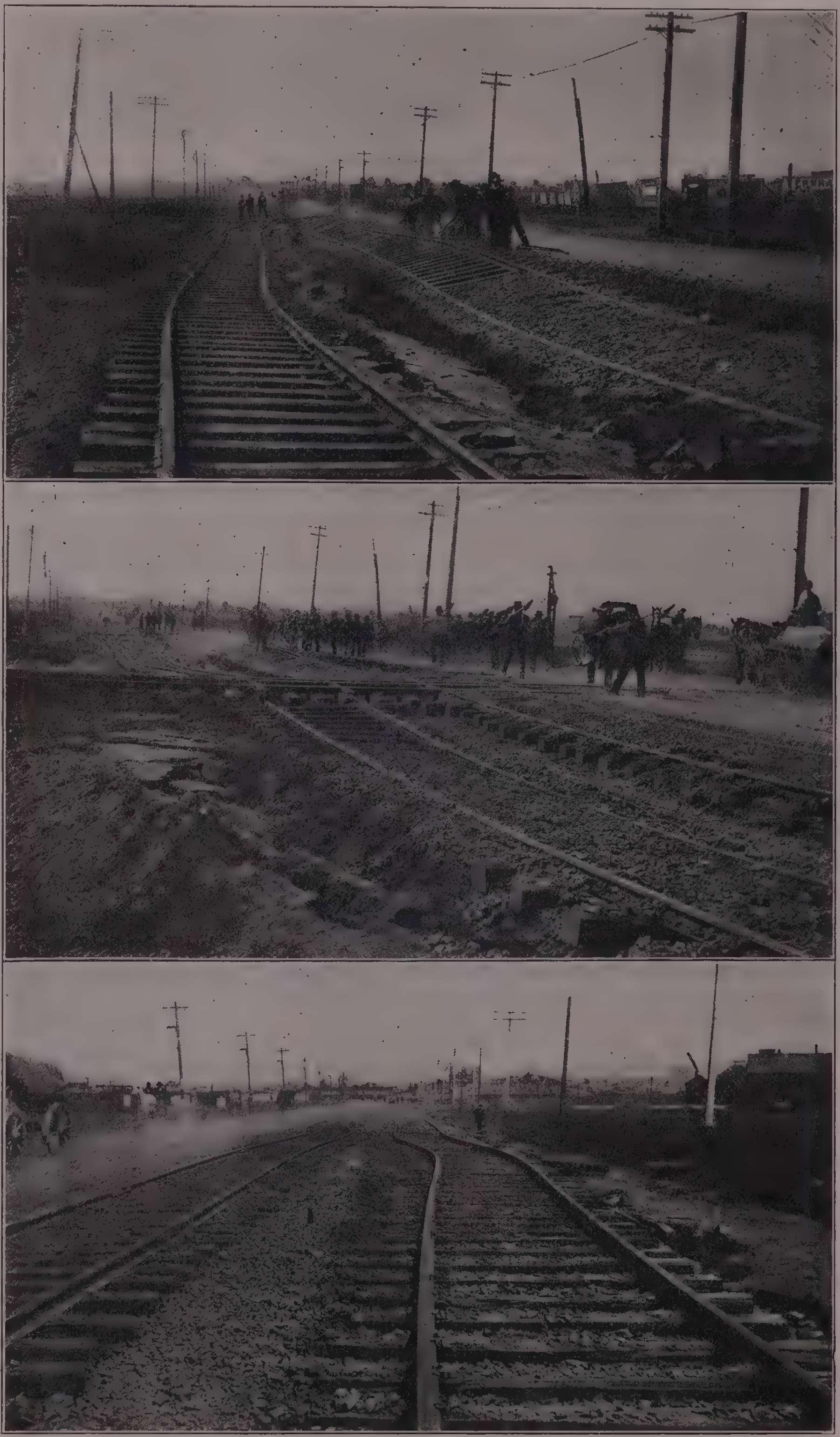
Brick buildings very generally failed to withstand the shock, either collapsing entirely or being so badly shattered as to be unsafe. Frame buildings were in almost as bad a plight. It was in the destruction of the brick and frame buildings of the more crowded portion of the old section of the city that the greatest loss of life occurred, people being crushed or imprisoned and later burned.

Heavy stone buildings were next in degree of damage. The massive new granite post-office building was very little damaged by the shock, this no doubt due to the steel frame.

In general it could be said that few buildings of brick or stone without steel frames resisted the shock to any great degree. A notable exception to this was the Palace Hotel, the brick walls of which resisted both shock and fire.

Of the modern large steel frame office buildings none were damaged by the shock so far as the eye could detect, except for the dropping of a piece of cornice or ornamental stonework here and there. The new Monadnock Building had brick veneering, and this was cracked some at the corners and between windows, but the interior was apparently unharmed. The buildings faced with stone showed no cracks. The older Mills Building showed no damage from the shock.

From my observation I should say that modern construction can be made to resist such shocks as this one, especially if reinforced concrete-steel be used.



Figs. 7, 8 and 9. Street Railway Tracks in Alameda, Cal.

The Heating and Ventilation of the New Tacoma High School.

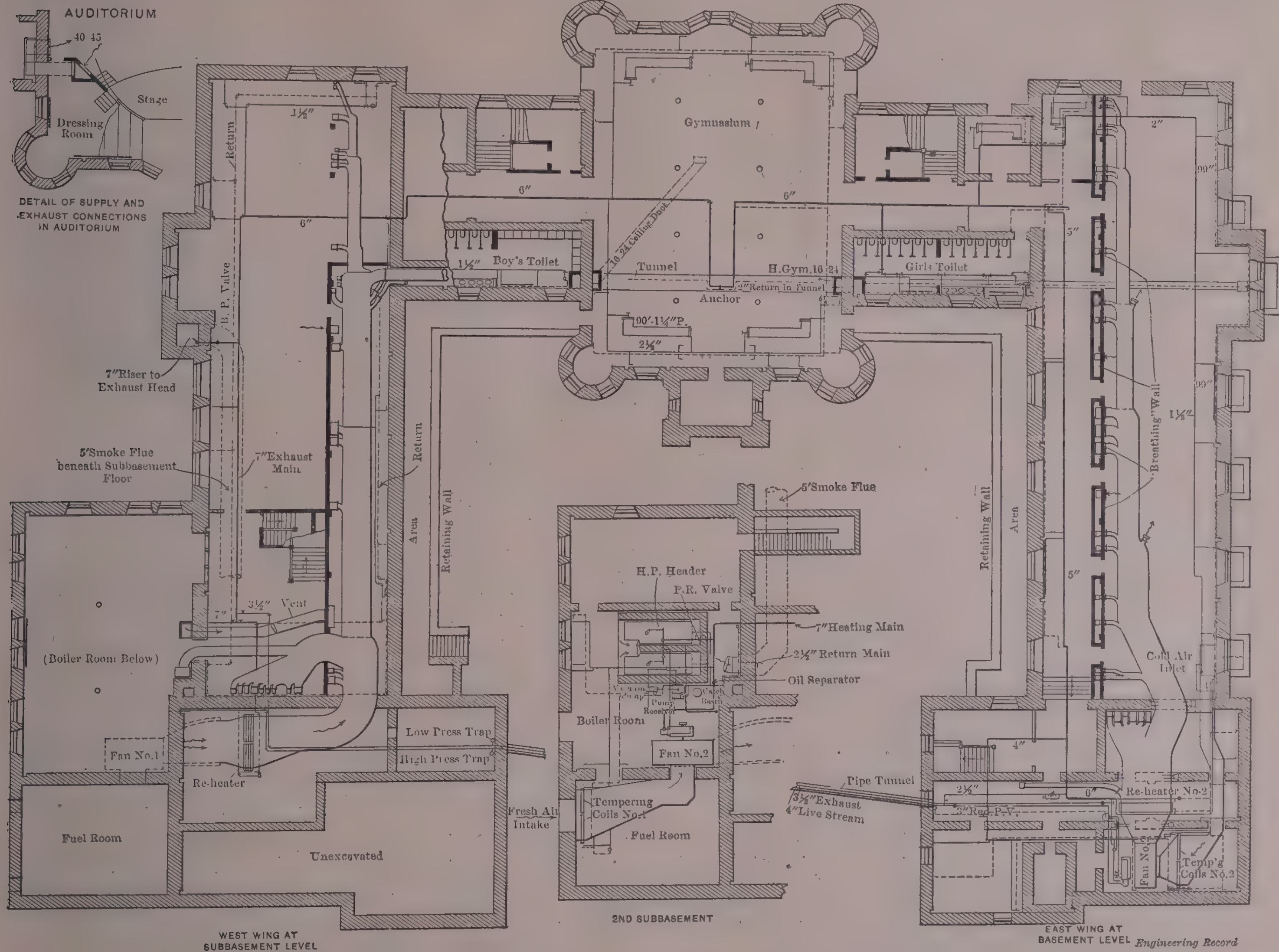
At Tacoma, Wash., a new high school has recently been completed by remodeling a large three-story brick structure, with basement and sub-basement, which had formerly been used for hotel purposes. It had been partially destroyed by fire, after which the building, with nine acres of ground, was secured by the city. It is located centrally with respect to the principal residential section of the city and is accessible by all car lines, so that it is well adapted for school purposes. It is beautifully situated on a promontory 250 ft. above water level, overlooking Puget Sound with its extensive shipping and the various snow-capped mountain ranges surrounding the city from 60 to 150 miles distant, including Mt. Baker to the north, Mt. Tacoma to the East, Mts. Adams, St. Helens and Hood to the south, and the Olympic range to the west.

The hotel was originally laid out on three sides of a hollow square, with a main entrance within the central court into a 65x86-ft. section of the building on the north side with four corner towers. The L-shaped side wings, each 50 ft. wide by 200 ft. long, are 200 ft. apart center to center and are joined with the central section by 50-ft. connecting wings. The two side wings are enlarged at their south ends to 80 ft. in width while the west wing has appended to it on the outer side, a one-story 42x95-ft. addition, with basement and first and second sub-basements, which provides for the mechanical plant. The building formerly had central halls through each of the wings with rooms on either side, but in the reconstruction for school purposes, a rearrangement of the interior was effected locating a 12-ft. hall on the court sides and class rooms of a minimum width of 28 ft. on the outer sides; additional stairways were also built near the ends of each side wing. In the large central entrance section there is an assemly hall on the second floor with a gallery at the third floor level, the whole having seating accommodations for nearly 1,000 pupils. The central entrance section and the enlarged corner and end sections of the wings are carried up to a fourth story, although that over the assembly hall is not used as yet.

The location of the building at this elevation, with resulting excessive exposure, its shape, entailing over 1,500 ft. of exterior wall line, and the extensive use of large windows, combined to render the design of the heating equipment a difficult problem. Ventilation was also required in all class rooms, the assembly hall, the gymnasium, and the other more frequented rooms. The heating is accomplished by a combination system of direct and indirect radiation, operated by exhaust steam with the Webster vacuum system of steam circulation and Johnson pneumatic heat regulating apparatus. The heating system is designed to warm the building to 72° F. when the outside temperature is at zero, except in the toilets, the manual training departments and the gymnasium, in which a maximum temperature of only 60° F. was desired. The ventilating system has been designed to supply 20 cu. ft. of fresh air per minute to each pupil, which supply was based upon an allowance of 15 sq. ft. of floor space to each pupil.

The first story addition to the southwest corner of the west wing takes advantage of a sharp declivity in the grade of the property at that point which permitted, in addition to the basement, a first and second sub-basement, the boiler room and mechanical plant being in the latter. This second sub-basement, which is 40x87 ft., is very nearly at grade so that access from the outside is easy and ample daylight lighting is available. The space is divided into a 25-ft. fuel room, a 37-ft. boiler and engine room and a 20-ft. room for office purposes. The floor above is of brick arches 8 in. thick sprung between 15-in. I-beams spaced 5 ft. center to center; the other floors in this section of the building are of concrete.

There are two horizontal return tubular shell boilers each 66 in. in diameter by 16 ft. long and of 70-h.-p. nominal rating at 80 lb. steam pressure. Each has 54 4-in. tubes expanded into ½-in. tube sheets and the shells are of ⅜-in. Otis flange steel with double-riveted horizontal seams. They have flush-front masonry settings with 22-in. double walls, fire-brick lined, and have 2-in. air spaces. They are fitted with plain hand-fired grates, having a total effective area of 24¾ sq. ft. The coal is handled manually from the fuel room, which holds about 200 tons; it is dumped into this room through holes in the roof, the grade of the yard permitting the wagons to be driven directly on to the roof. The products of combustion are removed by a 48-in. breeching of No. 14 steel which leads to a 5-ft. smoke duct beneath the floor of the sub-basement in the main section of the west wing alongside; this duct extends northward 78 ft. to connect with the main chimney rising 128 ft. above the grade of the



Engineering Record

Diagrams Illustrating General Ventilating and Heating Arrangements. Tacoma High School.

boiler-room floor. The boilers have 3½-in. pop safety valves and combination water columns with low-water alarms, fitted with 1¼-in. connections in which crosses are used instead of angles to facilitate the cleaning of the pipes, as is also the case in the blow-off piping. The latter consists of a 2½-in. header at the rear of the settings with a 2-in. connection to each of the boilers through straightaway valves and plug blow-off cocks, and discharges into a catch-basin in the boiler room which is drained to a point outside the room on the side hill. This catch-basin is a cast-iron tank, 2 ft. in diameter by 3 ft. deep, closed at the top and vented by a 1½-in. pipe to the roof, into which the blowoff and drip connections from the pumps, oil separator, exhaust head and engine cylinders are discharged. The feed delivery is connected to the boilers through the blow-off header, into which the feed pump delivers through a gate valve and check valve in series.

The boilers are supplied by a Worthington automatic feed pump and receiver which collects and returns the condensation from the heating system; the pump is a 6 by 4 by 6-in. duplex steam pump controlled by a float in the receiver to return condensation from the receiver to the boilers as fast as it accumulates. There is a 1¼-in. Penberthy injector in reserve, which takes its supply from the city water service and delivers through the pump feed line. The vacuum pump for the Webster return system, is a 8x6x12-in. Deane duplex steam pump taking its suction through a Webster strainer with cleaning attachment, from the 3-in. return main of the heating system and delivering through an air-separating standpipe to the pump receiver; this standpipe is a length of 5-in. pipe, 8 ft. high, into which the 2½-in. delivery line from the pump connects at about 18 in. from the top and the bottom of which delivers to the receiver. The pump is controlled by a Webster governor so as to maintain a practically constant vacuum in the return lines, thus pumping at varying rates to remove condensation and air as fast as it passes the return traps on the radiators and heating coils.

The high-pressure piping system centers in an 8-in. steam header over the boilers with 6-in. branches to each, from which a 3½-in. supply connection is taken off to blower engine 1 in the boiler room, a 4-in. connection for blower engine 2 in the east wing of the building some 280 ft. distant, a 2-in. branch to supply the steam pumps and injector, and a 3½-in. connection for the reducing valve to supply live steam to the heating system. All supply connections are graded with the flow of the steam, while the boiler branches are graded so as to return condensation by gravity to the boiler. The steam lines to the engines have Kieley vertical separators which are drained by Kieley steam traps so connected as to discharge either into the steam heating mains or to waste into the catch basins. The exhaust steam system consists of a 6-in. line in the boiler room with a 4-in. branch to fan engine 1, a 2-in. connection from the vacuum pump, a 1½-in. branch from the feed pump and a ¾-in. connection to the air compressor, which leads to a 6-in. Webster horizontal oil separator for the removal of entrained oil before entering the heating system. The separator is drained by a 1¼-in. drip line leading to the catch-basin in the form of a water-sealed loop, the top of which is about 18 in. from the bottom of the separator in order to overcome the maximum pressure or vacuum carried in the low-pressure system. Beyond this point, the exhaust line serves as the heating main, a 4-in. branch extending across the boiler room to serve radiators on the floors above. Just beyond the oil separator there is the live steam supplementary connection for the addition of live steam to the system when the exhaust is not sufficient; this conection consists of a 3x6-in. Kieley special vacuum-regulating pressure-reducing valve with 2-in. bypass for manual operation. Beyond the live steam connection, the heating main is increased to 7 in. and extends into the sub-basement of the adjoining west wing and northward to an atmospheric exhaust riser for relief from excess pressure or for use at times when heating is not required. The back-pressure valve in the atmospheric exhaust riser is a 7-in. Kieley noiseless valve, while the exhaust head on the riser near the top of the chimney is of the Lyman type with a 1¼-in. drip line carried back to the catch-basin.

The exhaust and live steam connections to the low-pressure heating main in the boiler room are supplemented by a similar arrangement of connections, but of smaller capacity, in the opposite extremity of the building where blower equipment 2 is installed. The 4-in. high-pressure steam line supplying this boiler is carried a distance of 280 ft. from the boiler room crossing the 98-ft .open space between the south ends of the wings in a tunnel. At the entrance to the east wing basement, there is a 2½-in. branch to a 2½x5-in. Kieley pressure-reducing valve for a second live-steam supplementary connection to the heating main, which at this point of the building is of 5-in. pipe. The high-pressure main continues as a 3-in. line to supply the blower engine, the drip pockets in which and the separator at the engine being drained by Kieley traps. These normally deliver the condensation to the low-pressure heating main, but have direct connections to the catch-basin for wasting in summer time when the heating is not required. The blower engine exhausts through a 3½-in. Webster oil separator into the low-pressure heating main at a nearby point, and also has a 3½-in. connection leading back through the tunnel to the west wing, where a connection is made to the 7-in. exhaust line near the atmospheric exhaust riser. The tunnel between the wings consists of 18-in. tile pipe with tight cement joints, which is laid from 5 to 12 ft. beneath the surface between the two buildings, as shown in the plan; both steam and exhaust lines are drained at the lower end, where they enter the west wing, by high and low-pressure traps, the former discharging to the heating main and the latter to the catch basin. All high-pressure, exhaust and heating main piping has molded asbestos covering, with the exception of the return lines which are run bare.

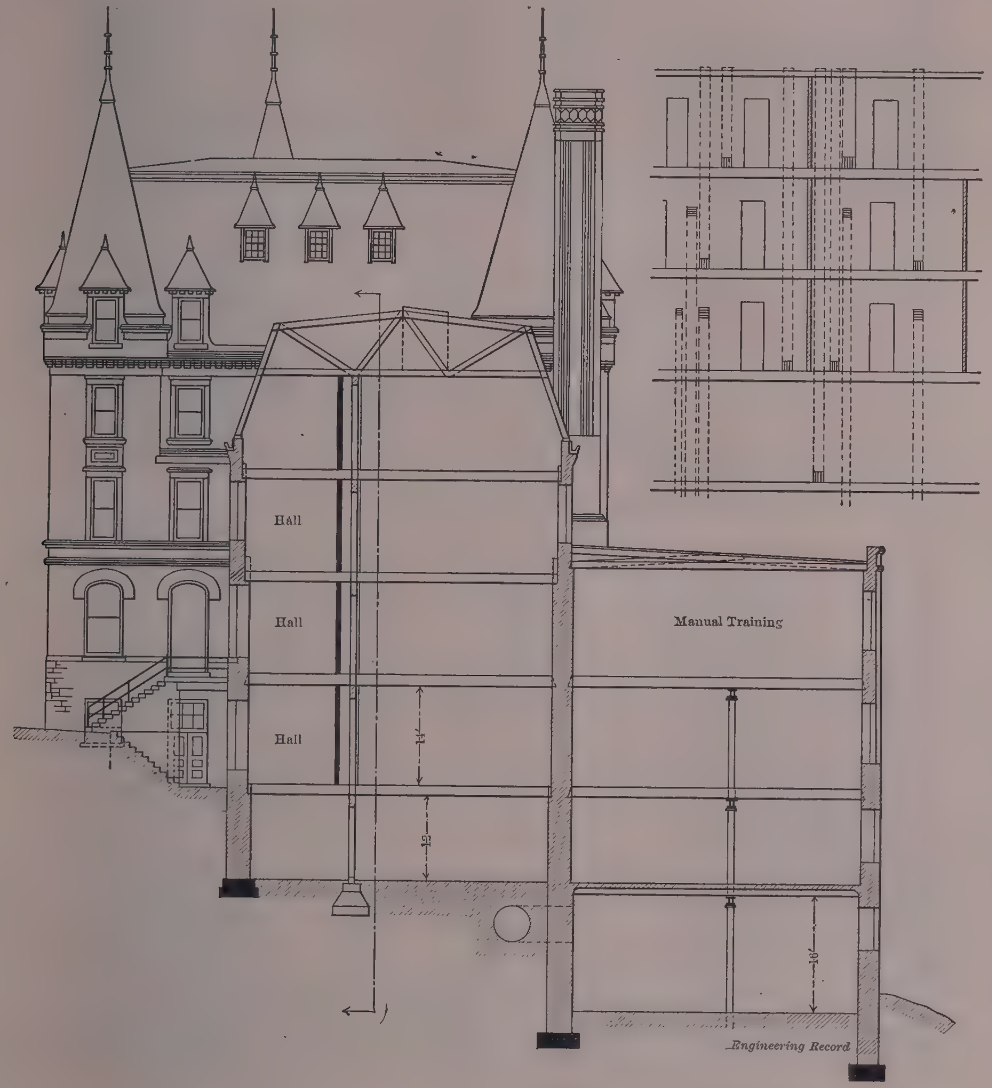
The heating system originates in the 7-in. exhaust steam line in the boiler room, which extends into the adjoining first sub-basement to the atmospheric exhaust riser branch; from there, it continues as a 6-in. line to the north end of this wing where it rises to the basement proper and is carried eastward through the central portion of the building to the east wing. In the east wing it is a 5-in. main, at the south end of which the second live steam supplementary and engine exhaust connections are made as above noted. This main is pitched 1 in. in 20 ft. in the direction of the flow of steam for the drainage of condensation, and at numerous points ¾-in. drainage connections are made from drop legs or pocket points in the main to Webster water and air relief seal motors which connect to the return system. The principal drainage points are near the north end of the west wing, where the main rises to the basement proper; at the east end of the main extending under the central portion of the building, and at two points in the south end of the east wing. Expansion in the section of 6-in. main under the central portion of the building, between the east and west wing divisions, is provided for by a branch loop extending 20 ft. at a right angle to the line of the main and rigidly anchored at the middle of the loop.

The radiators on the upper floors are supplied from the heating main by a number of risers, of which there are fifteen for the west wing, eighteen for the central portion and fourteen for the east wing. The risers for the side wings in most cases supply radiation on the third floor only, as the indirect system is used exclusively in most of the classrooms. The two on the court side of each wing supply the hall radiation and consist of 1½-in. lines tapering to 1 in. at the third-floor connections. The other risers are of varying sizes according to the amounts of radiation supplied, a number of them consisting of 1-in. pipe tapering to ¾ in. at the third floor while the largest risers consist of 2-in. pipe tapering to 1¼ in. at the third floor; the latter are the risers upon the north side of the central portion of the building, where extra radiation is required. All direct radiators used are of the Colonial wall type of the American Radiator Co., and have been installed in the 5, 7, and 9 sq. ft. sections. They are supplied, with the exception of those under automatic control, through Jenkins disc radiator valves in the ¾-in. size on radiators of less than 60 sq. ft., 1 in. on 65 to 100 sq. ft., and 1¼ in. above 100 sq. ft.

The return mains and risers which connect with the Webster radiator relief valves, parallel those for the heating supply. The risers are of ½ and ¾-in. pipe throughout; ½ in. being the smallest size used, and discharging into branch lines which deliver to a common 2-in. return main in a trench extending from the east to the west wing. It is thence carried on the ceiling of the first sub-basement to the boiler room, enlarging to a 2½-in. main near the latter point, and to 3 in. in the boiler room, where two more return branches join in. The return branches in the basement and sub-basement rooms are run on the baseboards to connect into the return header in the cross tunnel.

The indirect system is used in the greater part of the building in consequence of the necessity for mechanical ventilation in the school rooms, direct radiation being depended upon entirely only in some of the basement rooms, in the corridors and in the smaller offices and auxiliary rooms. The basements are served by indirect radiation only in the 27x144 ft. chemical laboratory in the east wing where there are two 16x28-in. registers and three 18x20-in. exhaust openings, which were necessary for purposes of ventilation; the direct radiation here consists of two 99 sq. ft. radiators. In this department, as in the physical laboratory, the direct radiation has been proportioned for heating at night, when the indirect system is not in use, to 60° F. in zero weather, so as to prevent freezing. The 28x102-ft. physical laboratory in the north end of the west wing basement depends entirely upon a direct heating equipment consisting of three 81-sq, ft. radiators. The toilets, the manual training departments and the gymnasium are similarly designed for heating to 60° F. independently of the indirect system. The gymnasium, occupying the entire 60x80-ft. basement floor level of the enlarged central portion has a direct equipment of four ceiling coils, each consisting of 90 ft. of 1¼-in. pipe, or a total of 156 sq, ft. of heating surface, and has also a 20x24-in. register from the indirect system through which will be delivered normally about 3,500 cu. ft. of tempered air per minute.

The remainder of the building is mainly heated by the indirect system, direct radiation being used principally to supplement the other in sections where north and northwest exposure is encountered. The 32x60-ft. library on the main floor level above the gymnasium has a 20x24-in. register from the indirect system, supplying 3,000 cu. ft. per minute and, owing to the northern exposure, two 81-sq. ft. radiators next to the windows. The assembly hall which occupies the whole of the second and third stories of the central portion of the building above the library and corridor, has two 40x45-in. registers near the stage which together supply about 15,000 cu. ft. of tempered air per minute; owing to the northern exposure of this room at the rear of the hall, and the large amount of window surface the indirect supply is supplemented by six 108-sq. ft. radiators on the second floor at the rear and four 99-sq. ft. radiators on the third floor. Of the class rooms, only those on the second floor with northern exposure and those on the third floor have direct radiation to supplement the indirect. In the cases of northern exposure 81-sq. ft. radiators are used in rooms 28x34 ft. in size or approximately one square foot per 12 sq. ft. of floor area. In the remaining class rooms on the third floor the indirect heating is supplemented by direct in proportions of about 1 sq. ft. to 16 sq. ft. of floor area in the more protected rooms and 1 sq. ft. to 13 sq. ft. of floor in the more exposed corner and projecting rooms.



Section Through West Wing and Partial Elevation of "Breathing Wall."

There are two distinct indirect systems, one in either wing; the blower for the west wing is located in the boiler room in the second sub-basement, while that for the east wing is in the south end of its basement. Each fan has tempering coils in the air intake from the outside which have capacities for heating the air to a maximum of 65° F., and also reheating coils in the delivery with bypasses directly to their systems. There are two main delivery ducts in either wing, one for the tempered and the other for the reheated delivery, which are carried longitudinally through the basement, with numerous branch connections to the riser ducts. The blowers are each three-quarter housed horizontal-discharge steel plate fans built by the American Blower Co., fan 1 in the west wing having a blast wheel 9 ft. in diameter by 4½ ft. wide, and a capacity of 50,000 cu. ft. per min., while that for the east wing fan 2, has an 8-ft. blast wheel, 4 ft. in width, and has a capacity of 40,000 cu. ft. Each fan is driven by a direct connected horizontal balanced-slide-valve engine. That for fan 1 is a 15x10-in. engine, operating at 135 r.p.m., and that for fan 2 a 13x8-in. engine, operating at 150 r.p.m., both designed to drive their fans at rating with a steam pressure of 25 lb. The engines are mounted on heavy bases on separate foundations from their blowers so as to prevent communication of vibration to the delivery duct systems, and reducing valves are used in their steam supply connections to insure the maintenance of uniform steam pressures at the engine throttles in spite of possible variations in pressure at the boilers, for uniform engine speeds and unvarying results in the air deliveries of the fans.

Each blower system has its inlet through a window in the outside of the building and in the intake duct, there is a two-section four-row tempering coil, that for system 1 having 2,076 ft. of 1-in. pipe, while system 2 has 1,656 ft. Each reheating coil is an eight-section four-row heater with 8,300 ft. of 1-in. pipe for system 1, and 6,624 ft. of 1-in. pipe for system 2. These heaters are supplied with steam from the heating main through individual 2½-in. valved connections to the base of each section, while the returns are 1¼-in. connections through a dirt pot and a Webster seal motor to the return main. All tempering coils and reheaters have full-size bypass ducts with automatically controlled dampers, by which the temperature of the delivered air may be adjusted for any range. These are balanced, brass-mounted dampers and each is controlled by the Johnson damper-operating motors actuated by thermostats on the delivery side of the heaters. The air delivery is carried to the fresh air supply risers in two ducts, one for the reheated air and the other for the cooler tempered air from the bypass connection; the areas of these ducts leaving fan 1 are 96x35 in. for the reheated delivery and 96x30 in. for the tempered air, while those for system 2 in the east wing are 144x24 in. for the reheated delivery and 144x18 in. for the tempered delivery. These ducts are carried along the ceiling of the sub-basement, reducing uniformly in section as the branch connections are taken off, and at each supply connection to a riser there is a mixing damper similar in construction and automatic operation to the bypass dampers in the heaters, except that these mixing dampers are controlled by thermostats in the rooms which their riser ducts supply.

The arrangement of both fresh air and exhaust, duct work is novel in that special "breathing" partition walls are used for their concealment. These consist of hollow partition walls, 36 in. thick, between the halls and class rooms on all floors of the side wings, in which ample space is afforded for both duct systems without interference with the room arrangement or the daylight lighting from windows. This provision was to a large extent due to the fact that the building had been originally built for other purposes, and remodeled without provision in the side walls for the ducts.

The general arrangement of the supply riser connections in the basement and that of outlets in the various class rooms is indicated in the accompanying drawings. All fresh air supply outlets in the various rooms are located at a uniform height of 8 ft. above the floor, which in connection with the positions of the exhaust registers at the floor line results in downward ventilation. The supply connections are in the majority of cases located centrally in the "breathing" wall with respect to the room, except in a number of the smaller rooms, where the supply registers are located toward the rear, opposite the seating. The indirect system was designed to supply 20 cu. ft. of fresh air per minute for each pupil, which design was applied to the rooms on the basis of a minimum allowance of 15 sq. ft. of floor area per pupil. In the assembly hall, which has a seating capacity upwards of 1,000, the supply has been proportioned for an average maximum attendance of approximately 800.

The exhaust ducts for the class rooms correspond exactly in number, cross-sectional area and size of register openings, with the fresh air ducts. Their inlet registers are in all cases at the floor level, from which the ducts are carried up through the "breathing" wall to the attic space, into which they open, the outlet to the exterior being made through louvres around the skylights. These ducts are without dampers or means of regulation. The ventilation of the toilets is in general provided for through special fixtures to the exhaust vent stacks in corners of the interconnecting wings in which the toilet rooms are located. These vent stacks, which are also used for housing several exhaust riser flues from certain of the rooms in the main four-story section of the building, are equipped for induced draft with coils of three lines of 1¼-in. pipe, 20 ft. high, with the necessary low-pressure steam and return connections. These stacks are carried up alongside the four-story central portion of the building, ending in louvred openings for the discharge.

Practically all of the rooms of the building having fresh air supply connections and also those having automatically controlled radiation, have Johnson temperature regulating thermostats from which the mixing dampers or the radiator diaphragm valves are pneumatically operated. For compressed air supply there is a 3x2x4-in. steam-driven compressor in the boiler room, automatically controlled by a pump governor to maintain a pressure of 20 lb. in the air piping throughout the building. This piping is of armored lead tube and is concealed throughout. There are in all 48 rooms under automatic control, requiring 50 thermostats, 50 mixing dampers and 46 radiator valves.

The heating and ventilating plant was designed by F. H. Heath, official school architect of the city of Tacoma, by whom the plans for the reconstruction of the partially destroyed hotel building were prepared. The heating and ventilating contractor was C. A. Richardson, of Tacoma, this contract amounting to $24,917. The property was purchased originally for $35,000, and the cost of reconstruction was about $190,000, making the total cost $225,000, which is about one-half of its present value.

A Special Flanged Water Main.

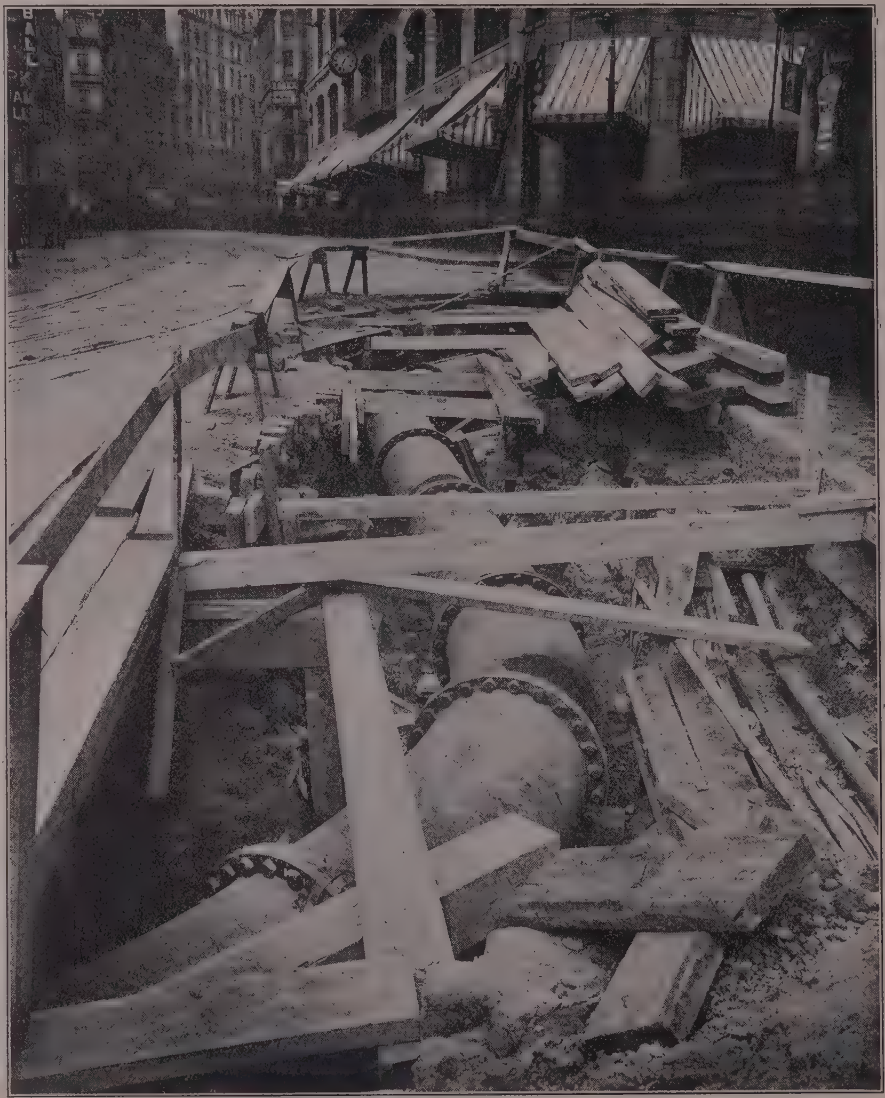
The subway construction in Washington Street, Boston, involved an entire relocation of the water pipe system in that street in the neighborhood of Boylston and Essex Streets. It was necessary to connect a 36 in. main in Boylston St. with a main of the same size in Essex St., and this involved a crossing of Washington St. where the limitations were such that two right angles were necessary in the location within 25 feet of each other, making a large letter S. Under the existing conditions, it would have been exceedingly difficult to provide for the unbalanced pressure by any ordinary system of bracing or tie rods. It was accordingly decided to use 30 in. flanged pipe making, in effect, a special casting about 77 ft. long. The joints were made with rubber gaskets, the machined faces of the flanges being coated with white lead before the gasket was put in place, allowing the rubber to squeeze out freely. The outside of the joints was surrounded by a collar of cement mortar to protect the bolts and the gasket. The only bracing used was a concrete strut at each end of the straight portion of the pipe. The work was done under the general direction of Mr. William Jackson, city engineer.

Blue-Printing from Thick Paper Drawings is now done by a process in which the paper is changed from opaque to translucent, at the same time fixing the drawing and making the paper waterproof. Drawing made with pencil or otherwise on white paper are placed on a feeding table between contact ribbons and are drawn by the machine through a bath and thence between calendering rollers which deliver the sheets at the point where they were inserted in the machine in about 45 seconds. The calendering rollers are hollow and one of them is heated by a gas flame. The effect of the treatment is to intensify the lines and prints made from the treated paper are stated to be as distinct as those from ink tracings. Good results are secured even with very thick paper, and it is said that the treatment does not swell or shrink the paper. If it is necessary to correct the drawing after the paper has been treated, the surface can be removed, new lines made, and the paper again passed through the bath to restore it to the uniform transparent condition. The machines now on the market have a capacity for 14 x 24-in. sheets of paper, but a modification of the machine is being constructed which will receive a roll of paper 40 in. wide and of indefinite length. The machines are manufactured by Charles R. Crabb & Co. of Brooklyn N. Y.

The Drainage of Earth Roads.

At this season of the year the drainage of earth roads is a particularly timely topic, and attention is therefore drawn to a valuable bulletin on the subject written by Prof. Ira O. Baker and published by the University of Illinois. It is primarily written for the conditions in the prairie States, but its points are so clearly stated that their application elsewhere can be made readily. The author points out at the outset that the removal of surface water is but one object of underdrainage, which is primarily intended to lower the water level in the soil and to aid in drying the ground quickly after freezing weather.

Tile Drainage.—The best and cheapest method of securing underdrainage is to lay a line of porous or farm tile 3 or 4 ft. deep on one or both sides of the roadway. It should be uniformly burned, straight, round in cross-section, smooth inside and have the ends cut off square. Before the introduction of tile for agricultural drainage, it was customary to secure underdrainage by digging a trench and depositing in the bottom of it logs or bundles of brush, or a layer of broken stone; or a channel for the water was formed by setting a line of stone on each side of the trench and joining the two with a third line resting on these two. Apparently it is still the practice in some localities to use such substitutes for ordinary drain tile. Tiles are better, since they are more easily laid and are less liable to get clogged. Tiles are cheaper in first cost, even when shipped considerable distances by rail, than any reasonably good substitute, and the drains are much more durable.



A Flanged Water Main in Washington St., Boston.

Tiles are laid simply with their ends in contact, care being taken to turn them until the ends fit reasonably close. In some localities there is apparently fear that the tile will become stopped by fine particles of soil entering at the joints, and consequently it is specified that the joint shall be covered with tarred paper or something of the sort; but in the Mississippi Valley, where immense quantities have been laid, no such difficulty has been encountered. With a very slight fall or even no fall at all, tiles will keep clean if a free outlet is provided and they are not obstructed by roots of trees.

In some localities it is apparently customary to use collars around the ends of the tile to keep them in line. If the bottom of the trench is made but little wider than the diameter of the tile, or if a groove is scooped out in the bottom of the trench to fit the tile, no difficulty need be apprehended from this source.

The following formula is sometimes employed to determine the amount of water removed by a tile; but it is only approximate and results obtained with it are only mathematical guesses. The formula is useful only in a locality where there is no local experience with tile; and its chief value consists in showing the relation between capacity and grade, and the effect of a variation in the diameter of the tile. It is $A = 1.9 \surd(f d^5 \div l)$, in which A is the number of acres for which a tile having a diameter of d inches and a fall of f feet in a length of l feet will remove 1 in. in depth of water in 24 hours.

The best practice in agricultural drainage provides for the removal of 0.5 to 1 in. of water per day; but since the side ditches will assist in removing rain water from the road, it is probable that a provision for the removal of half an inch per day is sufficient for the underdrainage of a road. If the ground is "springy," the ordinary provisions for underdrainage should be increased.

It is not wise to lay tile smaller than 4-in., and probably not smaller than 5-in. Tiles cannot be laid in exact line, and any tilting up of one end reduces the cross-section. Again, if there is a sag in the line equal to the inside diameter, the tile will shortly become entirely stopped by the deposit of silt in the depression. It is sometimes wiser to lay a larger tile than to increase the fall. Again, it may be better to lay a large tile near the surface with smaller fall than to lay small tile deeper with a greater fall. Ordinarily, the deeper the tile the better the drainage, although 3½ or 4 ft. deep is usually sufficient.

There is no danger of the grade of the tile being too great, and the only problem is to secure sufficient fall. A number of authorities on farm drainage and also several engineering manuals assert that a fall of 2½ or 3 in. per 100 ft. is the lowest limit that should be attempted under the most favorable conditions; but practical experience has convinced Prof. Baker that a much smaller fall will give good drainage. In central Illinois and northern Indiana there are many lines of tile having falls of only ⅙ to ¼ in. per 100 ft., which are giving satisfactory drainage; and not infrequently ordinary porous tiles laid absolutely level directly upon the earth in the bottom of the trench, without collars or other covering over the joints, have given good drainage without trouble from the deposit of sediment.

If possible at reasonable expense, the grade should be at least 2 in. per 100 ft.; and should never be less than ½ in. per 100 ft. unless absolutely necessary. On level or nearly level ground the fall may be increased by laying the tile at the upper end shallower than at the lower.

The individual tiles should be laid in line both vertically and horizontally, with as small joints at the end as practicable. The drain should have a free and adequate outlet. The end of the line of tile should be protected by masonry, by plank nailed to posts, or by replacing three or four tiles at the lower end by an iron pipe or a wooden box.

The prevailing prices for laying tile in loam with clay subsoil is about as follows: For 8-in. tile or less, 10 cents per rod for each foot of depth; for 9-in., 11 cents; for 12-in., 14 cents; for 15-in., 17 cents; and for 16-in., 18 cents. To aid in remembering the above data, notice that the price is 10 cents per rod per foot of depth for 8-in. tile or less, with an increase of 1 cent for each additional inch of diameter. The cost of a mile of 5-in. tile drain is usually from $200 to $250, exclusive of freight. If there is any considerable amount of work, the above prices for the smaller tile can be reduced 10 to 20 per cent.

Usually a line of tile 2½ to 3 ft. deep under the ditch at one side of the road will give sufficient drainage. Some tests made by the Illinois Agricultural Experiment Station seem to indicate that one line will give fairly good drainage under the most adverse conditions. The experiment consisted in the drainage of a piece of land selected as the worst that could be found in a part of the State notorious as having a large area of hardpan, which it was generally considered could not be underdrained "because the soil held water like a jug." Lines of tile were laid 2½ ft. deep and 50 ft. apart. The water level at a point midway between the lines of tiles was lowered 18 in. when at the same time the water level in the undrained portion of the field was only 6 in. below the surface. In this case the surface of the ground water had a slope of 1 ft. in 25 ft.

The traveled portion of an important road is usually not more than 50 ft. wide, and therefore a single line of tile 2½ to 3 ft. below the bottom of the side ditch, if of adequate size, will give nearly perfect drainage; and a second line will not greatly improve it. If a second line of tile is laid on the other side of the road it will drain only a comparatively small portion not reached by the first line. A single line well below the surface is far better than two shallow ones.

It is generally conceded that for agricultural drainage it is sufficient to place the lines of tile 100 ft. apart, provided they are of reasonable size and at sufficient depth. A tile will give agricultural drainage 50 ft. on either side of it; that is, a tile under only one side ditch will give agricultural drainage of the traveled way. More thorough drainage is required for agricultural than for road purposes, since when damp most soils will pack, which is harmful to agricultural land but beneficial to a road.

The above seems to prove that one line of tile, if of proper size and at sufficient depth, will afford sufficient drainage for road purposes; but nevertheless it is claimed by competent authorities that two lines are sometimes required. In some localities a stratum of hard-pan near the surface makes it necessary to lay the tile so shallow that two lines are really required; and sometimes the tile is so small or so poorly laid that one line is insufficient.

Some authorities recommend a line of tile under the middle of the traveled portion. A tile under the middle of the road is a little more effective than one at the same level under the side ditch; but the former is considerably more expensive to lay, since it necessitates more digging—whether the tile is laid before or after the road is graded. With the same depth of digging, a tile under the side ditch is more effective than one under the center of the road. Further, if the tile is under the center, there is liability of the settling of the soil in the trench, which will make a depression and probably a mud hole; and if the tile becomes stopped it is expensive to dig it up, and the doing so interferes with traffic. Finally, if the road is ever graveled or macadamized, the disadvantage of having the tile drain under the center of the road is materially increased.

Some advocate the use of a line of tile near the surface, on each side of the trackway, to secure rapid drainage of the surface. Very little, if any, water from the surface will ever reach a tile so placed, Prof. Baker believes, since the road surface when wet is puddled by the traffic, which prevents the water percolating through the soil. It is certain that in clay or loam the drainage thus obtained is of no practical value. Many farmers have tried to drain their barnyard by laying tile near the surface, but always without appreciable effect. The deeper the tile the better the drainage.

While a line of tile on one side of the road is usually sufficient, there is often a great difference as to the side on which it should be laid. If one side of the road is higher than the other, the tile should be on the high side to intercept the ground water flowing down the slope under the surface. Sometimes a piece of road is wet because of a spring in the vicinity, or perhaps the road is muddy because of a stratum which brings the water to the road from higher ground; in either case the source of supply should be tapped with a line of tile instead of trying to improve the road by piling up earth.

Side Ditches.—The side ditches are to receive the water from the surface of the traveled way, and should carry it rapidly and entirely away from the roadside. They are useful, also, to intercept and carry off water that would otherwise flow from the side hills upon the road. Ordinarily they need not be deep; but, if possible, should have a broad, flaring side toward the traveled way, to prevent accident if a vehicle should be crowded to the extreme side of the roadway. The outside bank should be flat enough to prevent caving, an important matter which is frequently neglected.

If the road is tiled as previously recommended, the side ditch need not be very large; but it should be of such a form as to permit its construction with the road machine or scraping grader, or with a drag scraper, instead of requiring to be made by hand. On comparatively level ground, the proper form of side ditch is readily and cheaply made with the usual "road machine." If a larger and deeper ditch is required, it can still be made chiefly and cheaply with the drag-scoop scraper.

A deep, narrow ditch is expensive to construct, and also expensive to maintain, since it is easily obstructed by the caving banks, by weeds, and by floating trash. Fortunately the shallow ditch is easy and cheap to construct and also to maintain. If it is necessary to carry water along the side of the road through a rise in the ground, it is much better to lay a line of tile and nearly fill the ditch than to attempt to maintain a narrow, deep ditch. A tile is very much more effective per unit of cross-section than most open ditches.

The side ditch should have a uniform grade and a free outlet into some stream, so as to carry the water entirely away from the road. No good road can be obtained with side ditches that hold the water until it evaporates. Piling up the earth in the middle of the road is perhaps in itself well enough, but leaving undrained holes at the side probably more than counterbalances the benefits of the embankment. It is cheaper and better to make a lower embankment, and to drain thoroughly the holes at the side of the road.

When the road is in an excavation, great care should be taken that a ditch is provided on each side to carry away the water so that it shall not run down the middle of the road. Every road should have side ditches, even one that runs straight down the side of a hill. Indeed, the steepest road needs the side ditch most, although it often has none. Frequently the water runs down the middle of the road on a side hill and wears it into gullies.

In a slightly rolling country the side ditch frequently has no outlet, and the water is allowed to accumulate at the foot of the slope and there remain until it is absorbed by the ground or seeps into a tile drain. Under such conditions the water seeps away very slowly, since the fine silt washed down from above forms an almost impervious coating which practically prevents any water from percolating through. The difficulty could be remedied by providing an inlet from the open ditch to the tile. This may be a well, walled with plank or masonry without mortar (except near the top) and having a grating in the side or top through which the water may pass. The well should be large enough to allow a man to enter it to clean it, and should extend a foot or more below the bottom of the tile. Earth roads in villages and towns are usually better provided with such inlets than country roads, but both could be materially improved at comparatively small expense by attention to this matter.

If it can be prevented, no attempt should be made to carry water long distances in side ditches, for large bodies of water are hard to handle, and are liable to become very destructive. Side ditches should discharge frequently into natural water courses, though to compass this it may in some cases be necessary to carry the water from the high side to the low side of the road. This is sometimes done by digging a gutter or by building a dam diagonally across the road, but both are very objectionable. A better way is to lay a tile or put in a culvert, the amount of water determining which shall be done.

It is sometimes necessary to carry water a considerable distance in the side ditches, as, for example, when the road is in excavation. This requires deep ditches, which are undesirable and dangerous; and if the grade is considerable, the ditches wash rapidly. In such cases it is wise to lay in a line of tile under the side ditch, and turn the water from the surface ditch into the tile at intervals. This can be accomplished readily by inserting in the line of porous tile a Y section of vitrified sewer pipe, with the short arm opening up hill. Of course, the short arm, i. e., the vertical arm, need not be as large as the body. If necessary two or three lengths of porous tile may be added at the upper end of the Y to make connection with the bottom of the open ditch. Earth, sods or stones can be piled around the upper end of the tile to make a dam and to hold the tile in place.

As a rule, side ditches will not have too much fall, but sometimes a ditch straight down a hill will have so much fall as to wash rapidly, in which case it is an advantage to put in an obstruction of stone or brush. In extreme cases the bottom of the ditch is paved with stones.

Surface Drainage.—The surface drainage of a road is provided for by crowning the traveled way and keeping it smooth. The making of the road crowning in the beginning is a matter of construction, and the keeping of the surface smooth is a question of maintenance. It should be remembered that water upon the surface of the road cannot be carried away by the underdrains until after it has penetrated and softened the road surface.

The slope from the center to the side should be enough to carry the water freely and quickly to the side ditch; and if the surface is kept free from ruts and holes, less crown will suffice than if no attention is given to keeping the surface smooth. If there is not enough crown the water cannot easily reach the side ditches, and the road soon becomes water-soaked.

On the other hand, the crown may be too great. If the side slopes are so steep that traffic keeps continually in the middle, the road will be worn hollow and retain the water instead of shedding it promptly to the side ditches. With the ordinary method of caring for earth roads, more water stands on a very convex road than on a flatter one. If the crown is too great, it is difficult for vehicles to turn out in passing each other. Again, if the earth is piled too high in the middle, the side slopes will be washed into the side ditches, which not only damages the road, but also fills up the ditches.

The slope from the center to the side should be at least 1 ft. in 24 ft.; and it should not be more than 1 ft. in 12 ft. If the surface is well cared for, the former is better than the latter; but in no case is it wise to exceed the latter slope.

The crown should be greater on steep grades than on the more level portions, since on the grade the line of steepest descent is not perpendicular to the length of the road, and consequently the water in getting from the center of the road to the side ditches travels obliquely down the road. If the water once commences to run down the center of the roadway on a steep grade, the wheel tracks are quickly deepened, stones are loosened or uncovered, and the road becomes rough and even dangerous. Under these circumstances, it is necessary to construct catch-waters at intervals to divert the water which runs down the road to the side ditches, thereby preventing the formation of gullies in the road surface. These catch-waters may be either broad shallow ditches or low flat ridges constructed across the road; and they may slope toward one or both ditches. In the former case, they should cross the road diagonally in a straight line; and in the latter case, in plan they should be a broad angle with the apex at the center of the road pointing up hill. There is little or no difference between the merits of the ditch and the ridge, unless the bottom of the former is paved with gravel, broken stone, or cobbles. The ridges are more common, but usually are so narrow and so high as to form a serious obstruction to traffic. However, neither the ditches nor the ridges should be used except on steep grades where really necessary, since either form is at best an obstruction to travel. The angle that the catch-waters shall have with the axis of the road should be governed by the steepness of the grade—the steeper the grade the more nearly should the catch-waters run down the road. They should have a considerable breadth so that wheels may easily ascend them and horses will not stumble over them.

Catch-waters should also be constructed in a depression where an ascending and a descending grade meet, in order that they may collect the water that runs down the traveled way and convey it into the side ditches. These catch-waters should run square across the road, and should be quite shallow ditches, the bottom of which is hardened with gravel, broken stone, or cobbles.

Some authorities recommend that a surface of the road on the face of hillsides should consist of a single slope inclining inwards. This form of surface is advisable on sharp curves, but Prof. Baker says it is of doubtful propriety elsewhere. Its only advantage is that the water from the road is prevented from flowing down the outer face of the embankment; but the amount of rain water falling on one half of the road cannot have a very serious effect on the side of the embankment. With a roadway raised in the center and the water draining off to either side, the drainage will be more effectual and speedy than if the drainage of the outer half must pass over the inner half. If the surface is one plane, the lower half of it will receive the greater share of the travel; and as it will be more poorly drained, it is nearly certain to wear hollow. This will interfere with the surface drainage; and consequently a road with this section will require excessive attention to keep it in good condition.

Whatever the form of the road surface, if the hillside is steep there should be a catch-water above the road to prevent the water from the hillside above from flowing down on the road. It should be, say, 6 ft. back from the excavation, and should have a width and depth according to the amount of water to be intercepted.

Maintenance.—Proper maintenance is as important as good construction. A distinction should be made between maintenance and repairing. The former keeps the road always in good condition; the latter makes it so only occasionally. A defect which could be remedied in the beginning with a shovelful of earth or a minute's time, if neglected may require a wagon load of earth or an hour's time, besides being in the meantime an annoyance or a danger to traffic. The better the state in which the road is kept, the less are the injuries to it by ordinary traffic and the weather. Water is the natural enemy of good earth roads. The chief object of maintenance should be to keep the surface smooth and properly crowned so that rain water will be shed promptly into the side ditches. These should be kept open so that the water may be carried entirely away from the road.

In the winter there frequently come times when the road is full of holes and ruts, while the surface soil is dry and mellow. This condition occurs most frequently when the ground below the surface is frozen. If at this time a harrow is run over the road, it will fill up the ruts and holes and leave the surface comparatively smooth. This improves the road for present travel, and gives a smooth surface which will greatly decrease the deterioration of the road by subsequent rains. The ordinary adjustable farm harrow should be used, and the teeth should be set to slope well back. The labor required is not great, since a 12-ft. harrow can be used, and then a single round is sufficient.

Often there are only a few hours in the middle of the day when the frost is out of the ground sufficiently to permit this work to be done, and therefore it is best for each farmer to harrow the road adjoining his own land. The work comes at a season of the year when the farmer's time is usually not very valuable, and hence the expense is small. This method of treating earth roads has proved very beneficial, both in securing good roads and in preserving them. In the summer, when the roads get roughed up, they can be materially improved at small expense by running over them with a harrow having the teeth down quite flat. If the roads are a little muddy, this treatment will make them dry faster, and also make them much more pleasant to use after they have dried.

In the early spring, just after the frost goes out of the ground, earth roads are usually full of deep ruts. The harrow is not suitable for the work now required. The object is simply to cut off the ridges and fill up the ruts, and thus break the way for travel. It is well to break the road early in the season, both to accommodate immediate travel and to hasten the coming of a better condition of the road. It is much more economical to make the road smooth with a railroad rail or its equivalent than to wear it down by travel.

A railroad rail 14 to 16 ft. long drawn by two two-horse teams has been used with great success in breaking down the ridges and filling up the ruts. The team is hitched to an eye fastened through the web 2 or 3 ft. from the end of the rail. The edge of the base of the rail serves as a cutting edge. A 7-in. steel I-beam is equally good.

When the ground is mellow and loose after freezing and thawing, the steel rail will smooth the road nearly as satisfactory as the road machine, and much more rapidly, since it cuts a wider swath and the draft is so light that the teams walk right along. One round trip is usually sufficient for any road. The time when the work is most advantageously done is comparatively limited; and therefore one rail should not be expected to cover too much road. The cost is so small that one can be provided for each few miles of road—the number depending upon the climate and the nature of the soil.

A heavy stick of timber, say 6x12 in., faced on one side with a steel plate, and drawn by a team, is very effective in smoothing the way for travel. To the top face of the timber should be fastened a frame by which to hitch the team. This frame should be in the form of a capital A with one leg a little shorter than the other, to cause the cutting edge to stand obliquely to the line of draft. This blade should be about ¼ in. thick, 4 in. wide, and as long as the timber, 6 or 7 ft.

Mr. D. Ward King deserves credit for the intelligence and persistency with which he has advocated the use of the split-log drag (Eng. Record, Feb. 24, 1906), in keeping smooth the surface of an earth road. If the surface of the road is kept smooth, the rain water is speedily drained into the side ditches and besides the road is always pleasant to drive upon.

A Concrete Highway Bridge having a central arch of 232 ft. span, with three 53-ft. arches on one approach and two on the other, has been designed by Mr. George S. Webster to carry Walnut Lane over Wissahickon Creek in Philadelphia. The central arch consists of two ribs 21½ ft. wide at the springing and 18 ft. at the crown, on which a series of light spandrel arches carry a 40-ft. roadway and two 8-ft. sidewalks. Each rib is 9½ ft. thick at the springing and 5½ ft. at the crown.

Construction of the Gallitzin Tunnel on the Pennsylvania Railroad.

All the traffic of the Pennsylvania R. R. that is carried across the summit of the Allegheny Mountains about eleven miles west of Altoona at Gallitzin, Pa., passes through three tunnels about 2,300 ft. above sea level. All east-bound traffic is carried through the double-track Portage tunnel originally built for the old Portage road about 1852, and widened and repaired for railroad service in 1898. Up to 1905 all west-bound traffic passed through the old Allegheny tunnel about 500 ft. north of it. The latter, which has a length of about 3,600 ft., was built about fifty years ago for double-track service. It has a horseshoe cross-section 24 ft. wide and 20 ft. high in the clear, and is therefore very narrow for a double track, although much wider than is necessary for a single track. Two tracks were laid in it and sometimes both were used simultaneously for freight service; but when a passenger train was on one track no train was allowed on the other. Since the recent completion of a new tunnel, each west-bound track passes through a separate tunnel, and both of the east-bound tracks passes through the Portage tunnel.

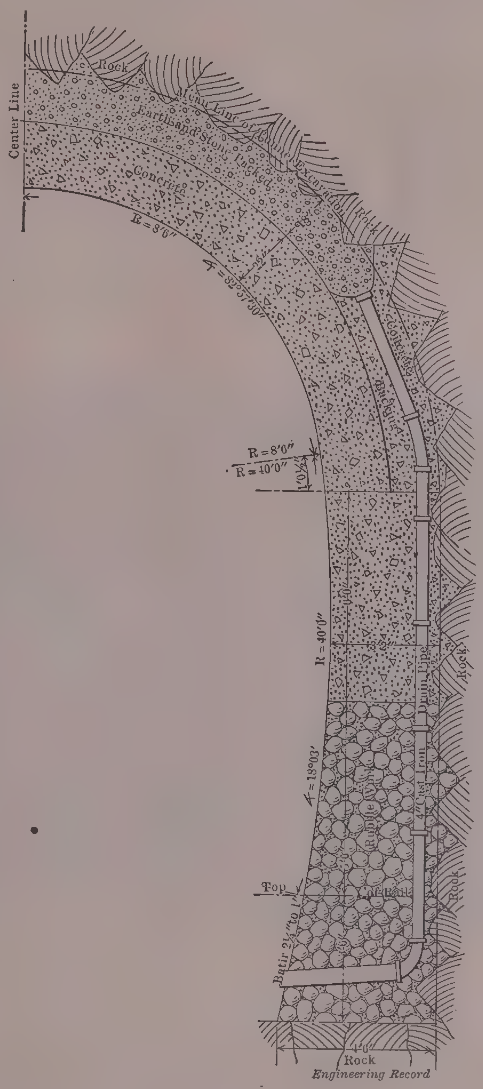
The new west-bound tunnel is parallel with the old one and 80 ft. from it on centers. It is on a tangent, has a down grade of 1 per cent. from west to east, and was driven through rock at an average depth of about 300 ft. above the roof. It has a horseshoe cross-section 17½ ft. wide and 20 ft. high in the clear above the top of rail. It has rubble masonry side walls 9 ft. high, and a concrete roof arch 22 in. thick, with a springing line 15 ft. above the bottom of the side wall. Refuge niches 6 ft. wide are built in the side walls 200 ft. apart on alternate sides of the tunnel.

The rock penetrated was not uniform and was composed of many different strata. At the west end it was chiefly sandstone and at the east end chiefly shale. Limestone, fire clay, slate and other materials were also encountered, but no difficulty was experienced from water. Some water entered through the west portal but, after running a short distance down the grade of the tunnel, disappeared through cracks in the floor into the workings of an old coal tunnel which sufficed to drain it. The tunnel was driven without shafts from top headings at both ends. These were started 14 ft. wide and 9 ft. high, being enlarged to the full width in advance of the bench work which was taken out in two lifts. The first one was about 7 ft. high and the second 10 ft. high. The excavation in the full-width heading amounted to 7 cu. yd. per linear foot, and that in the two benches amounted to 14 cu. yd., thus making a total excavation of 21 cu. yd. for the tunnel.

At the west end the work in the heading was easy and progressed so rapidly that the heading was sometimes 1,000 ft. in advance of the bench. It was excavated by a gang of thirteen men drilling 16 holes about 10 ft. deep with the use of four air-driven Ingersoll-Sargeant drills operated on two columns. At first they worked in a ten-hour day shift, but as considerable difficulty was occasioned by their tendency to overrun the time of the next shift they were put on an allowance of four holes per day for each driller, and it was then found that the work, instead of requiring 10 hours, was completed in 8 hours, thus allowing the air to clear after the blasting and afford an opportunity for the muckers to begin work without delay at the commencement of their shift.

The heading was enlarged by three holes on each side, which were drilled during the night shift while the permanent timber was being set and the top bench, which was not less than 50 ft. in the rear, was being drilled with a transverse row of six holes 7 ft. back of the face. These holes were shot at 5 o'clock in the morning and the muck from them was all removed by 10 o'clock in the morning. At this time the miners commenced drilling on the lower bench in which a transverse row of five holes were driven 14 ft. back from the face. These holes were sprung with two charges before the final blast; those in the upper bench being sprung with one charge. All blasting was done with Forcite gelatine.

All the muck was handled by two Marion A steam shovels with shortened dipper handles and booms, which worked at subgrade and loaded the muck into 3-yd. Ryan & MacDonald wooden side dump cars in trains of seven 3-ft. gauge cars. At the west end, where the grade was down towards the heading the three trains of dump cars were switched by a Lambert hoisting engine with a 200-ft. cable, which snapped them back from the steam shovel to the coke-burning locomotives that hauled them out of the tunnel to the spoil bank, a maximum distance of ½ mile from the portal. At the east end the grade was down toward the portal and no hoisting engine was required, since the cars could be pulled out by mules and were drawn to the dump by two locomotives.



Half Section of Tunnel.

Near the east end the tunnel encountered a coal measure about 4 ft. thick, making a vertical angle of about one degree with its axis. Its intersection with the heading was about 800 ft. from the portal and the presence of the vein made the work much more difficult, although for the same reason the bench work was somewhat easier. The coal measure had previously been partly worked and where the thickness of the shale and soft rock between it and the top of the tunnel diminished to a thickness of about 5 ft., it broke through and timbering had to be carried through it to the top of the old working. Here a large amount of timbering was required and generally it was necessary to support the arch timbers with intermediate verticals and side posts. The material in the heading was so loose and open that frequently satisfactory blasts could not be made and the charge would blow out above instead of removing the rock. The progress here averaged about 80 ft. per month, while at the west end where little timbering was required it was as much as 200 ft. per month.

All regular timbering was made with 10x12-in. pieces 10 ft. long, and the bents were spaced 2 and 3 ft. apart on centers. Twelve drills were installed in the two headings, and, together with the two steam shovels and the hoisting engines, were operated by compressed air from a plant about 600 ft. from the west portal of the tunnel. Here there was one straight-line, 24x30-in Ingersoll-Sargeant compressor with a capacity of 1,200 cu. ft. per minute, and one 20x24-in. compressor with a capacity of 800 cu. ft. Both of them were driven by a battery of four 80-h.-p. portable return tubular boilers manufactured by The Erie Iron Works. At night the steam shovels were not operated and the small compressor sufficed; in the daytime the large compressor generally furnished all the air necessary, but sometimes the small one was also required.

Air was delivered from the power house at a pressure of 100 lb., through a 6-in. pipe carried between the rails of the track to the old parallel tunnel. At the west portal a 4-in. branch was taken from this pipe and carried to the west heading of the new tunnel, being reduced successively to 3 and 2 in. as it advanced. The main pipe was reduced to 5 in. and carried through the old tunnel to the east portal where it was reduced to 4 in. and carried across to the new tunnel and returned in it towards the west heading, thus providing an air supply which was always conveniently accessible through its entire length.

The side walls were kept close to the lower bench and stone for them was delivered, mostly at night, from trains on the main track, sidings being provided only for turn-outs and for the empty cars. These walls were built by the day shifts and were made of mortar mixed by hand as required, using improved Union Rosendale cement. Single horizontal lengths of 6-in. cast-iron drainage pipes were built into the feet of the side walls and connected by reducing elbows to 4-in. vertical cast-iron pipes carried in the solid masonry or concrete backing up to the haunches where the open upper ends were covered with broken stone to collect drainage and discharge it into the gutters on each side of the track. The faces of the side walls were battered and curved and were carefully built to a line with vertical wooden templates set by transit and level.

Single rails were laid in the gutters close to the side walls and on them moved a falsework tower 20 ft. long, which was built of well-braced timber and was supported by four double-flange wheels on each side. This tower gave clearance through the center for dinkey trains and carried the centering for the concrete arch. When it was in service it was jacked up about 9 in., and the 2½-in. lagging was built up from both sides to the crown as required. When the steam shovels were at work all of the concreting was done by the night shift. As soon as they commenced work they set up a light trestle on each side of the tunnel just in the rear of the tower and on them, about 5 ft. above the track, placed a light platform which had previously been stored in a vertical position alongside the track where it would not obstruct the traffic. On this platform was placed a McKelvey concrete mixer operated by an engine driven with compressed air and served with material wheeled by hand upon the inclined platform. The mixer discharged into ½-yd. wooden scale pans on flat cars on the tunnel floor. The concrete was immediately pushed through the tower to the forward end and there raised to the working platform by a tackle operated by a double-drum Lambert hoisting engine.

It required three 10-hr. shifts to build one 20-ft. section of the roof arch. After this had set for 36 hr. or more, the falsework tower was lowered to a bearing on its wheels and was drawn forward by the dinkey locomotive. The concrete was mixed 1:3:5, using Giant Portland cement. At one end of the tunnel local stone was broken for the concrete. At the other end, the stone was not suitable and a supply was therefore purchased from the American Lime & Stone Co., Tyrone, Pa. Sand for the concrete was purchased from the Anchor Sand Co., at Altoona.

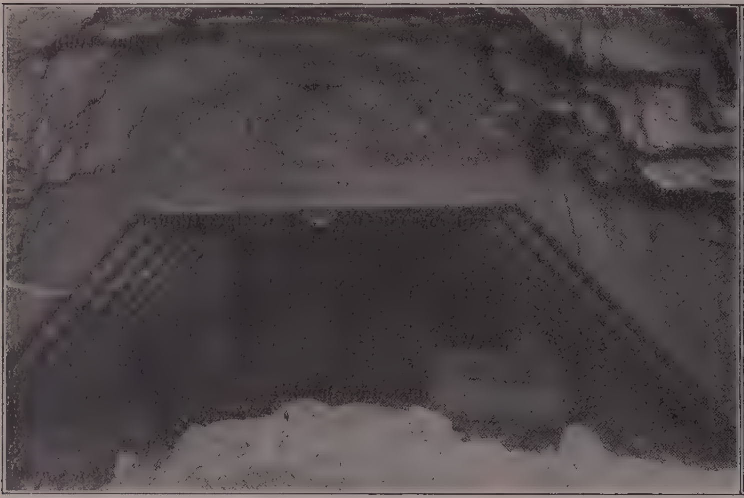
The total amount of concrete used in the tunnel was 12,000 cu. yd., for which 15,330 bbl. of Portland cement was required. The excavation required an average amount of 2½ lb. of explosive per cubic yard. About 2,000,000 ft. B. M. of permanent timbering was used, and the tunnel was built in 22 months by an average force of about 300 men, and cost about $500,000. Its construction affords a very interesting comparison with that of the old parallel tunnel of the same length and built under similar conditions. This was constructed entirely by hand work, using four shifts and six headings. Work on it was commenced in November, 1851, and it was finished in February, 1855.

In general the tunnel was not waterproofed, satisfactory results being attained with the ordinary concrete by providing the drainage pipes already mentioned. At the west portal, however, persistent leakage through the roof made it necessary to take special measures. A drift was made above the arch, the packing removed above it and a waterproofing of tar was carefully laid over the arch. Then the cavity was completely filled with dry rubble carefully packed in place around the permanent timbering. This treatment proved efficacious and no further trouble was experienced from leakage at this point.

After the completion of the tunnel it was found that great difficulty was experienced on account of the smoke and gases discharged there by locomotives. These caused the atmosphere to become so bad that the trainmen sometimes became unconscious and it was necessary to provide relief. This was done by constructing at the east end the ventilating apparatus illustrated in the accompanying views. It consisted of a sheet-iron hood about 50 ft. long, enclosing a track and having an inner surface coincident with the soffit of the tunnel arch and walls. The outer surface converged from the outer end of the hood to the portal of the tunnel so as to give it a wedge-shaped cross-section. A Sturtevant blower was installed at the end of the hood on each side and delivered air through it to the tunnel portal where a narrow opening in the inner face of the hood permitted the blast to be forced into the tunnel nearly parallel with its axis.

Trains pass through this tunnel in one direction only, and as the grade is up from this end they are usually drawn by two locomotives in front and one pusher behind. As soon as the forward locomotive enters the tunnel the fan is started and the large volume of air forced into the narrow space between the train and the tunnel lining drives the smoke and gas in advance of the locomotive so that its driver can keep the cab windows open and is supplied with an abundance of fresh pure air. The second locomotive does not work in the tunnel, and the smoke from the pusher never reaches the front of the train. This arrangement is considered efficient and satisfactory.

The tunnel was designed and constructed under the direction of the engineering department of the Pennsylvania R. R., during the administration of Mr. W. H. Brown, chief engineer; Mr. W. A. Pratt, assistant chief engineer, and Mr. C. S. d'Invilliers, engineer of construction. Mr. P. F. Bredlinger was the contractor for the tunnel construction, and Mr. C. S. Churchill was the patentee of the ventilation apparatus.



Heading in Good Rock.

Heading in Bad Rock.

Electric Iron Smelting by the Heroult process has been conducted at Sault Ste. Marie, Ont., under the direction of Dr. Haanel, who sent the following telegram regarding the results to the Dominion authorities at Ottawa: "Successful demonstration of all points stated in my memorandum on electric smelting of Canadian iron ores requiring investigation. Output greater than figure adopted by Harbord in report of commission. Subsequent substitution of charcoal, and therefore of peat for coke. Consumption of electrode insignificant. Production of nickel pig of fine quality from roasted pyrrhotite. Forty tons of pig have so far been produced. Process admits of immediate commercial application. Experiments will be completed in about two weeks."

A Comparison of Formulas for Concrete Beams.

In the discussion of Capt. J. S. Sewall's paper on reinforced concrete floor systems (Eng. Record, March 10) at a recent meeting of the American Society of Civil Engineers, Mr. Leonard C. Wason presented a discussion giving an interesting comparison of a number of leading formulas for concrete beams. His discussion was from a viewpoint entirely different from that of Mr. Henry Goldmark in his paper before the Canadian Society of Civil Engineers (Eng. Record, March 31), and its general features accordingly deserve review in these columns. The two contributions by Messrs. Goldmark and Wason sum up in an admirable manner the present status of beam formulas, and the latter author also gives a comprehensive discussion of the formulas for reinforced concrete floor slabs.

Mr. Wason's object was to show that sufficient data are now available to determine a formula accurate within allowable limits of variation for general use in designing beams of rectangular or T-section, and to emphasize the fact that the best results are obtained by solving for the working instead of the ultimate strength. The need of a generally accepted method of computation has been forced upon his attention through competition. In several cases where architects have specified spans and floor loads, and left the design entirely open to the bidders, work has been lost because competitors have put in lighter designs. In other cases, where a bid has been submitted, accompanied by plans, and, later, the designs have been submitted for review by a consulting engineer, the cost has been increased by more than 10 per cent., due solely to a difference in the formulas.

The nine formulas compared by Mr. Wason are based on different assumptions, all of which, from certain experiments, appear to have solid foundations. All are based on the same fundamental conditions, namely: 1, all tension is carried by the steel; 2, all compression is carried by the concrete; 3, there is a perfect bond or union between the steel and concrete within the limits of the stresses used; 4, the effects of shear are omitted, and failure is due to flexure only; 5, there are no initial strains, and the same examples solved by each, using the same constants, ought to give results directly comparable. The formulas are reduced to the same general form, and examples are solved, first, using the same constants for all; secondly, using the constants proposed by each individual writer. The results are summarized in the table. For his comparisons, Mr. Wason used a rectangular beam: span, 14 ft.; width, 12 in.; depth to center of reinforcement, 12 in.; total depth, 13½ in.

The following formulas were compared: The Wason formula, demonstrated in The Engineering Record of Sept. 21, 1901; the Hatt formula, discussed by Mr. Goldmark in this journal on March 31; the Thacher formula, discussed in the same issue; the Burr formula, deduced in Prof. Burr's "Elasticity and Resistance of the Materials of Engineering"; the Kahn formula, characterized by an unusual assumption concerning the cross-section in compression; the Talbot formula, explained in The Engineering Record of Aug. 13, 1904; Capt. J. S. Sewall's formula, explained by him in this journal on March 10; the Warren formula, forming the basis of a handbook recently published and providing for taking up some tension by the concrete.

An examination of the results in the table will show that in three of the nine cases there is a fairly close agreement with each other, whether with the use of the same constants for all, or the constants recommended by each author, although the assumptions of each are quite different. The three which agree fairly well are: Wason, Hatt and Talbot. Without doubt, Mr. Wason says, the stress diagram of the concrete in compression is a curve somewhat resembling a parabola. No allowance for tension of concrete should be made. There seems to be, among many writers, a lack of appreciation of the fact that results obtained by solving for the ultimate strength of a reinforced concrete beam, then dividing by a given factor of safety, or using the corresponding working stresses to solve for the working strength of a beam, do not give the same results or results which can be compared.

Ventilating Apparatus at Portal of the Gallitzin Tunnel.

The correct method is to solve for the working strength. Assuming a working compressive stress of one-fourth the ultimate, the difference between the straight line and the parabola is negligible, and the triangular area can be used, as it is simpler. The variation in the quality of the best concrete will more than offset the refinement of retaining the curve. If the triangular area is used for ultimate compression, the result will be too large, in the ratio of ½ to 5/16. The modulus of elasticity is used only in finding the position of the neutral axis, is order to find the center of gravity of the compressive force. The position of the neutral axis is of very little value.

In a large number of tests examined, the neutral axis for one-quarter of the ultimate load has been found to be not far from one-half the depth from the top of the beam to the center of reinforcement. It is sometimes above and sometimes below. To assume it half way, agrees very closely, therefore, with the observed facts. With this position and a straight-line distribution within the working stress, the center of gravity of the compressive stresses is two-thirds of the distance up from the neutral axis to the top of the beam. Therefore, the arm of the moment of resistance is 0.833 *d*.

SUMMARY OF RESULTS USING THE SAME CONSTANTS:

Author.	Ultimate bending moment, in pounds.	Breaking load, in pounds.	Area of steel, in square inches.	Stress in steel, in pounds per square inch.	Distance, top to neutral axis, in inches.	Arm of moment of resistance, in inches.	Arm, as percentage of *d*.
Wason	750,000	35,714	1.5	50,000	6.00	10.00	0.833
Hatt	795,939	37,906	1.5	50,000	3.93	10.53	9.877
Thacher	445,499	21,214	0.82	50,000	3.43	10.86	0.905
Burr	552,180	26,294	1.50	34,920	4.37	10.54	0.878
Johnson	708,750	33,750	1.35	50,000	4.50	10.32	0.86
Kahn	710,250	33,821	1.50	50,000	6.74	9.47	0.789
Talbot	759,000	36,143	1.50	50,000	5.02	10.12	0.843
Sewell	348,860	16,612	0.64	50,000	2.91	10.95	0.913
Warren	504,000	24,000	2.24	50,000	8.16	9.28	0.773

SUMMARY OF RESULTS USING EACH AUTHOR'S CONSTANTS:

Author.	Ultimate bending moment, in pounds.	Breaking load, in pounds.	Area of steel, in square inches.	Stress in steel, in pounds per square inch.	Distance, top to neutral axis, in inches.	Arm of moment of resistance, in inches.	Arm, as percentage of *d*.
Wason	750,000	35,714	1.5	50,000	6.00	10.00	0.833
Hatt	775,226	36,915	1.5	50,000	4.66	10.25	0.854
Thacher	634,936	30,235	0.87	70,400	4.99	10.33	0.861
Burr	855,879	40,756	1.5	53,940	4.38	10.54	0.878
Johnson	641,850	30,564	1.32	50,000	4.41	10.35	0.863
Kahn	909,120	43,291	1.5	64,000	6.74	9.47	0.789
Talbot	737,250	35,107	1.5	50,000	5.78	9.83	0.819
Sewell	674,870	32,137	1.46	45,000	4.8	10.27	0.856
Warren	756,000	36,000	2.78	53,000	7.36	9.55	0.792

In Mr. Wason's practice, he has never known a case where a floor was composed of concrete leaner than 1:3:6, or richer than 1:2:4, and as a designer will generally use one mixture at all times, there is no complication by a large number of ratios of areas of steel to concrete, as the percentage is a fixed amount determined entirely by the working stress of each material. In using such a formula as his, it is as easy to check existing work designed by others as to design new work independently by it.

Some engineers solve for the working stress of the beam, and use the parabolic curve for the compressive stresses. This is inaccurate, inasmuch as, within the working stresses, the stress is almost exactly proportional to the strain, so that a plot is either a straight line or its difference from a straight line is negligible. With this method of design, the outside fiber stress in compression is actually about 1½ times as great as it is assumed.

Mr. Wason recommends using the sum of the dead and live loads as the load on which the factor of safety is based, except in the rare cases where the dead load is larger than the live load, when (live load + .4 dead load) × 2½ = the elastic limit of the steel, may be used. The limit of elastic deformation determined by Prof. Bauschinger was about seven-tenths of the ultimate resistance; therefore, approximately, the above factor of safety is based on the elastic limit of the concrete as well as of the steel.

In designing, it is assumed that there are no initial strains in the composite structure, but, nevertheless, they exist, as the shrinkage of the cement in setting produces an initial compression in the steel which the formula does not recognize, and this, if neglected, adds to the factor of safety. Inasmuch as the amount of stress cannot be accurately determined, this is the wiser course.

From every test which has come to Mr. Wason's attention, he is convinced that there is no economy in reinforcing the beam with steel against compression. There is not as great economy in using it in compression as in tension, but he goes still further and says from his present knowledge, that it is never advisable to use steel in compression in beams. The tests made for him at the Masachusetts Institute of Technology showed no value whatever in top reinforcement, and to rely on it would be dangerous. There are other reasons to prevent a theoretically accurate design from being actually carried out on the work. As the ultimate strength and modulus of elasticity increase with age, while the steel does not, the design of the beam becomes unbalanced, thus changing the ratio of the moduli of the two materials, the position of the neutral axis, and, especially important, the ultimate compressive stress, thus changing the expected result from any design where these items are used as factors. Actual transverse tests, where the neutral axis has been located, show that the outside fibers sustain a greater stress than in columns uniformly compressed.

On work of any size, the concrete is mixed by machinery, while laboratory tests are almost invariably mixed by hand. Samples of hand-mixed concrete from actual work give better results than laboratory specimens. In two sets of tests, reported at the Watertown Arsenal in 1897 and 1900, the difference in strength between hand-mixed and machine-mixed concrete, where both cases were exceptionally well done, was 11 per cent. in favor of the machine-mixed. In the other set, under commercial conditions, the difference was 25 per cent. in favor of the machine-mixed. There is quite a difference in the modulus of machine-mixed and hand-mixed concrete. Wet or plastic mixtures thoroughly or lightly tamped affect the density and the bond with steel.

The bond or union between the steel and the concrete increases with age. The adhesion does not reach a very high value in one month, but increases steadily beyond this point for a number of months. Thus, a design based on adhesion which would not be safe at one month would be safe at a greater period. A mechanical bond is always to be preferred to simple adhesion, however. While the formulas given take no notice of this, the designer must, before completing his work.

Fortunately, all these variations are in the direction of safety, but when natural causes, of which the most elaborate formula can take no cognizance, produce such differences, why attempt great refinement, especially when the values of the several factors cannot be determined with absolute precision?

There are many rules in practice for the quantity of concrete necessary to embed the steel in the bottom of a beam. The method followed by Mr. Wason, which has proved entirely satisfactory in twelve years of practice, is to use a quantity equal to twice the diameter of the bar below its center. In work of exceptional importance, or where there is unusual danger from exposure to fire, this may be increased to 2½ times the diameter of the bar, and this will be found to be ample in the worst cases. The width of the beam should be at least equal to 3 times the diameter of the bar. If this is used as a minimum, there is danger in some cases of shear cracks. Adding an inch to the amount above given, or, at most, 4 times the section of the bar, will be found sufficient for beams reinforced with a single bar. When more than one is used, allow a clear space between the bars equal to their diameter.

A good deal has been said by various writers about the percentage of steel to use. The limiting factor is the area of the concrete. After once determining the working stress of this, the percentage of steel is fixed for any given stress, and this ratio is a constant.

Among the advantages of solving for the working stress, in addition to those previously advanced, is the fact that a great many tests of the crushing strength of concrete of different mixtures and brands of cement have been made when measurements have not been taken to determine its elastic quality. A general average of all these is easy to obtain, or an average omitting the exceptionally high ones, and this may be used as the ultimate strength. In obtaining results of this character, there is no danger of misinterpreting their meaning. The variations in the actual results from those theoretically expected are well within the limits of allowable error. The advantage in commercial practice of all work of different designers agreeing in their principle with one another is as important as in designs made for wood and steel.

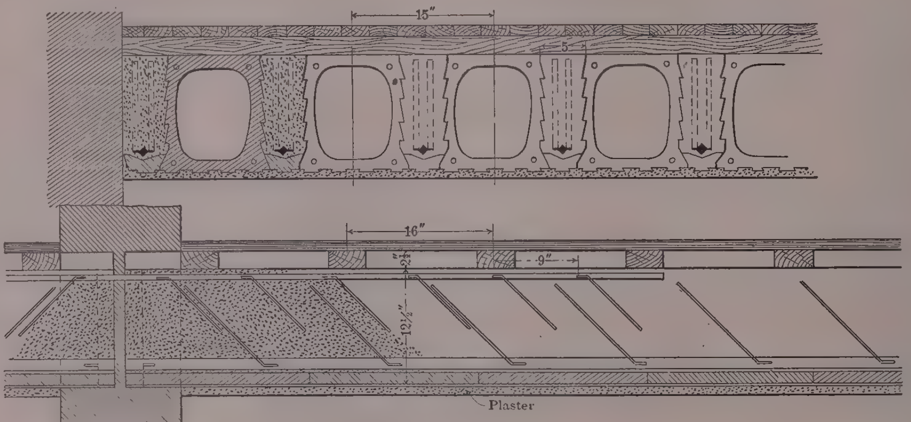
In all the foregoing, nothing has been said about web stresses. When Mr. Wason began constructing this class of work, twelve years ago, he did not know enough to reinforce the beams against shear. There are a good many structures without any reinforcement which have proved entirely satisfactory in actual service. On account of this experience, he still continues to build many floors for light loads without any web reinforcement. There is one building, however, in which the floors are habitually heavily overloaded by the shock of falling weights. In this, some beams have been cracked, which would indicate there is not a very large factor of safety, and therefore reinforcing against web stresses is desirable. From the experience of actual structures without web reinforcement, and from laboratory tests, it is evident that the concrete will withstand a considerable part of the web stresses, enabling the beam to develop nearly the ultimate strength of its tension and compression members.

When beams are to carry a quiet load, or one with but little vibration, the concrete can be allowed to resist shear to the amount of 80 lb. per square inch. But when there is heavy vibration or sudden shocks, reinforce for the entire web stress. On account of the frequent lapse of time between filling a beam and spreading the panel or flange portion of the floor, it is advisable to use stirrups bent to extend at least 1 ft. each way from the beam into the panel to bond the two together. This is seldom done. It is most needed at the center of the span. Deformed bars are far superior to plain ones, in Mr. Wason's opinion, and, now that there is little difference in price between them, there is no excuse whatever for the use of plain bars.

In comparative tests, where some of the main bars were bent diagonally upward, reaching the top of the beam near the support, the greatest strength was obtained—25 per cent. greater than with the use of diagonal stirrups attached rigidly to the main bars. This latter method, however, is far superior to diagonal stirrups which are loose, as in tests of this kind, when the beam deflected, they dragged under the main bars, breaking away the concrete and causing failure at a lower load than a beam which had no web reinforcement whatever. Loose vertical stirrups gave better results than beams without any web members. It is harder work to embed diagonal web members properly than vertical ones, or where some of the main bars are bent diagonally upward to the top of the beam. Therefore, to obtain as good results with the inclined stirrups requires more expense and smaller stone in the concrete than is required with other types.

Dome and Floor Construction in the United States War College.

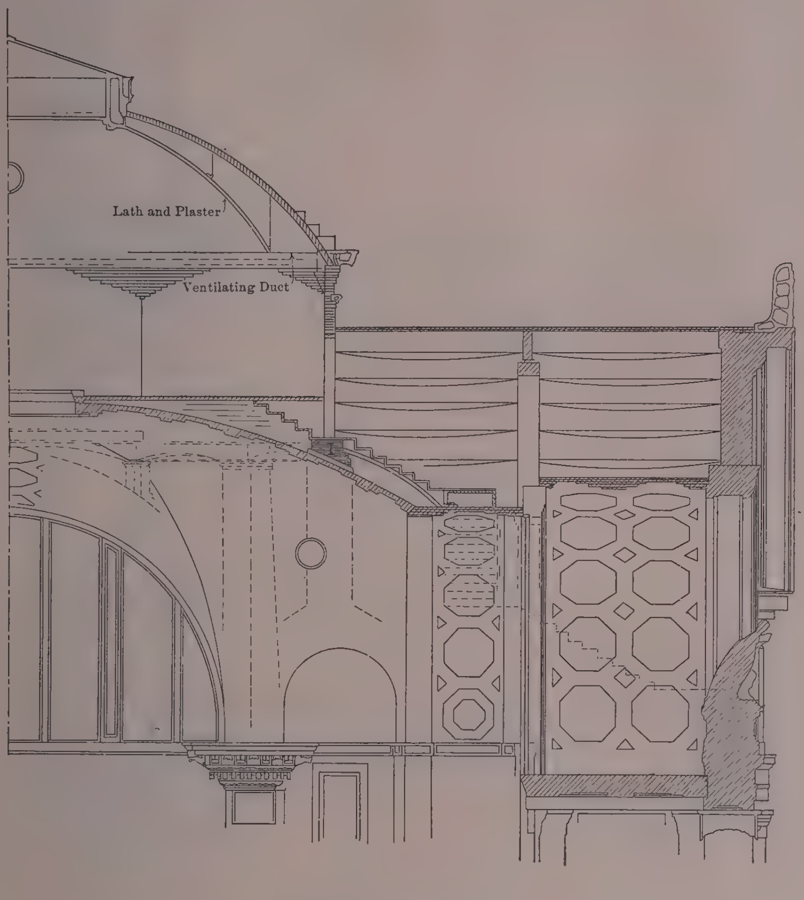
The new War College for the Engineer Post of the United States Army at Washington, D. C., has a 300 x 104 ft. rectangular plan with a semi-circular extension 63 ft. in diameter in the middle of one long side. It has two full stories and a basement throughout and there is a third or gallery story much narrower than the lower stories which forms a clerestory above the lower roof and, with the central transept, forms two intersecting wings surmounted at their intersection by a segmental dome 42 ft. in diameter in the clear which is supported on longitudinal and transverse arches forming the circumscribing rectangle. The building is of a monumental character, costing $700,000 inclusive of about $90,000 for the terrace by which it is approached. The basement and lower stories are sub-divided by solid walls or rows of piers and columns in transverse lines 33 ft. on each side of the center and in longitudinal lines about 19 and 28 ft. on each side of the axis. These provide longitudinal corridors from end to end of the building on each side of the principal rooms, a 37 x 110-ft. two-story map room at one end of the central corridor and a library of corresponding dimensions at the other end. On each side of these rooms there are smaller exterior rooms for officers, committees, and various purposes, and in the semi-circular extension there is a large two-story lecture room.



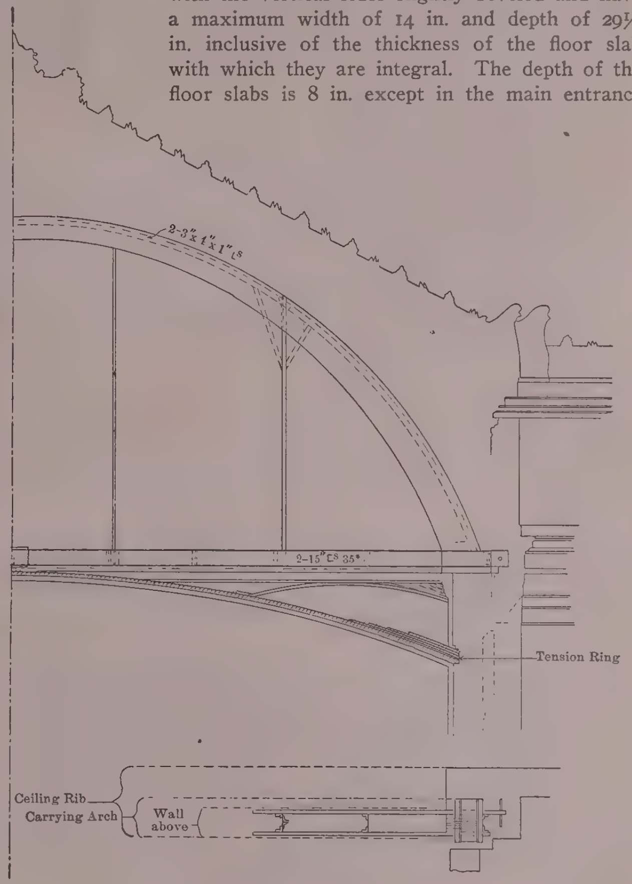
Floor System of the United States War College.

Between the map room, library and lecture room, the central part of the building under the dome forms a single lofty apartment approximately 60 ft. square, which is obstructed only by the four symmetrical rectangular piers that carry the dome at a total height of 88 ft. from the main floor to its skylight. This hall is the central feature of the building and is surrounded by balconies at the second and gallery floor levels. Its ceiling is formed by a flat segmental dome carried by longitudinal and transverse arches sprung from the four sides of the large rectangle. A circular opening in the center of the dome admits light and air from the space above, which in turn is covered by a second dome of greater convexity and smaller span, surmounted by a circular raised skylight. All of the domes and arch ceilings are of Guastavino construction and on account of their magnitude and structural features they possess unusual points of interest. Wherever this construction carries the roof it is built up to the proper exterior slope and the roof finish is applied directly to it.

The entire opening for the lecture hall penetrates the south gable wall of the building and it was at first intended that the wall should be carried across it on a plate girder. When, however, it was attempted to provide masonry bearings for the girder it was found very difficult on account of the small area available and the presence of large stones with heavy moulded projections which themselves required a good wall bearing and interfered with the girder seats. The difficulty was overcome by substituting for the plate girder an arch rib of the Guastavino type made with many courses of flat tiles. This arch has a clear span of 60 ft. and a rise of 22 ft. It is about 30 in. deep radially at the skewback, 18 in. deep at the crown, and 30 in. wide. The feet of the arch bear against skewback angles riveted across the top flanges of a pair of 15-in. horizontal channels which take up the thrust leaving only direct vertical pressure for the masonry to sustain. A pair of curved 3 x 4-in. angles are set in the face of the rib and, with the vertical angles which connect them to the horizontal channels, receive the framework for the large semi-circular window. The ceiling under this arch is not hung from it but is separately formed with another independent segmental Guastavino rib 5 ft. wide which has the same span and a rise of about 6 ft.



Half Section of Roof.



Elevation of Tile Rib.

The construction of the upper dome is very simple. The shell consists of three courses of tile forming a spherical segment of 41 ft. clear span and 10 ft. rise. The upper part is pierced with a circular opening 15 ft. 8 in. in diameter, bound with a ring of 3x4-in. angle iron and surmounted by the walls and roof of the skylight. The seat on the top of the wall is provided by a ring of 8x8-in. angle iron serving for a skewback bearing to receive the thrust. It also provides a convenient anchorage to which the overhanging terra cotta cornice blocks are hooked. It has its outer surface covered with copper and from it is suspended the segmental spherical plate ceiling, with a space of 2 or 3 ft. between the two domes to serve as a ventilating duct for the discharge of foul air through the louvre surrounding the skylight.

This ceiling covers the upper gallery below which there is a larger main dome covering the great central hall. This dome has a rise of 20 ft. and is a sort of groined arch, supported by four large piers and by the intersecting arches in the four sides of the hall. It carries no weight except its own dead load and the load imposed by the octagonal walls of the upper dome. The inner surface has a geometrical pattern made in it by the addition or removal of part of successive courses of tiles. Adjacent to this dome are the vaulted ceiling of the library, lecture room and map room which are of similar construction. They support the pitched roofs above them, and are especially interesting on account of the support of portions of the arches by other arches at right angles to them. The low side roofs over the second story outer rooms are composed of reinforced concrete and hollow tile floor construction with separate ceilings of the same type of construction about 4 ft. below them.

The roofs and floors are all supported on the walls, interior partitions and longitudinal girders connecting the interior columns, no transverse girders being used except in the central hall. The upper floors and roofs, except where Guastavino arches are used, are constructed of tiles in long rows alternating with narrow strips of concrete reinforced by Kahn truss bars so as to virtually make floorbeams of spans up to about 18 ft. The ends of these beams are seated on the brick walls or are made integral with the main girders. Where they are supported on partition walls the ends of the beams on opposite sides of the wall have only a short clearance between them and are connected across the wall by short reversed bars in the upper parts of the beams.

The tiles used for these floors are of special pattern with webs parallel to the reinforcement rods. Vertical longitudinal surfaces of the blocks are provided with saw tooth grooves so as to develop a strong shearing surface in contact with the concrete beams. The lower edges of the blocks are beveled to provide keys for small separate blocks connecting them and forming the bottoms of moulds in which the concrete is cast for the reinforced beams. The under surface of all the blocks has beveled slots to key with the ceiling plaster. In the office rooms the floors are covered with wooden boards nailed to screeds set on the terra cotta blocks and having the spaces between them filled solid with cinder concrete. All other floors have some form of granolithic or mosaic wearing surface. The first floor is made with solid concrete slabs reinforced with Kahn and plain round bars.

The longitudinal floor girders are of the ordinary reinforced construction and like the floorbeams are of 1:2½:5 concrete made with Atlas and Nazareth Portland cement mixed in a Campbell concrete mixer. The girders are all made with the vertical sides slightly beveled and have a maximum width of 14 in. and depth of 29½ in. inclusive of the thickness of the floor slab with which they are integral. The depth of the floor slabs is 8 in. except in the main entrance where it is 6½ in., and over the vault where it is 10 in.

The gallery in the upper part of the map room is cantilevered about 4 ft. beyond the face of the wall and is of Guastavino construction supported on tees anchored in the reinforced concrete floors of the adjacent corridors. It is made with 4x4-in. T bars about 5 ft. long and 4 ft. apart on centers, which are fulcrumed on the top of the corridor wall and are anchored by projecting about 18 in. into the ends of the corridor floorbeams, where they have transverse horizontal pins.

The building is considered especially interesting on account of the very small amount of steel which is required for a structure of its size and containing so many wide spans. The interior will be finished either with plain plaster or with plaster relieved by buff brick piers, pilasters, etc. The work is being executed mainly by day labor under the direction of Mr. John Stephen Sewell, captain, corps of engineers, U. S. A., and it is expected that it will be ready for occupation during the present year.

Notes on the Design of Swing Bridges, from a Maintenance Standpoint.

A paper read before the Western Society of Engineers by C. H. Cartlidge, Bridge Engineer, Chicago, Burlington & Quincy Ry.

In looking over a number of plans for swing bridges by different engineers, the writer has been struck by the absence of provision for certain functions, relatively unimportant, yet affecting both the ease and cost of maintenance. A few of these have been noted, and in the present paper will be touched upon briefly. No attempt will be made to discuss the question of design of draw spans in a broad sense, either from a mathematical or structural standpoint. The few points presented are simply some of those which have arisen during the writer's experience, and they are touched upon in order to invite discussion of their value. In the designs which are described here there is little which is original, but the details have been selected because of their fitness for their duty, as demonstrated by our experience in maintaining these and other structures.

A study of various plans is a profitable preliminary to any designing, as it is often to be found that existing conditions have been satisfactorily met. By going over them all, eliminating such details as seem unsuitable, and selecting the good ones, it is possible to make of the composite, a really good design. A choice, however, must often be made between two or more apparently equally good details, and this is true in the case of the sort of center to be employed.

In swing spans, the choice of the type of bearing to be used lies between three, each of which has its advocates. These may be classified as 1, center bearing; 2, rim bearing; 3, combined center and rim bearing. A center-bearing turntable, in which all loads are carried to the pivot, was at one time the most popular. As in this case there is no drum, with its complicated stresses and doubtful distribution of the loads on the wheels, the comparative certainty of the mathematical work appealed to designers. Some provision has to be made, however, against the span while being turned, and trucks running on a circular track must be connected to the drums by girders of considerable strength, so that the theoretical simplicity is not realized.

One great advantage which accrues to a center bearing is that of ease of turning, and while everything is new and in adjustment this advantage is realized. Should there be any excessive wear, however, this is soon lost, and it is necessary to make bearing areas as large as practicable, in order to prevent such wear.

The complications, referred to above, involved by the use of a rim-bearing center, are more theoretical than actual, as experience with spans of widely varying length has demonstrated. The drum should, of course, be deep enough to avoid deflection, and if there is headroom to permit this, a rim bearing will be found extremely satisfactory, especially if the span is of moderate length. For spans up to 300 ft. the writer usually employs this style of center, such as the rim bearing center for the draw span of the Illinois River Bridge, at Beardstown, Ill.

The points seeming to the writer most worthy of note as affecting the cost of maintenance will be mentioned in turn. You will note the depth to which the pivot castings are sunk into the concrete piers. This is an important detail, and this treatment obviates a good deal of trouble from loosened anchor bolts and consequent loosening of the pivot. Much difficulty of this sort has been encountered in the past. A rigid pivot, such as this anchorage provides, permits much less chattering and vibration when the bridge is turning than one which will allow of any play whatever.

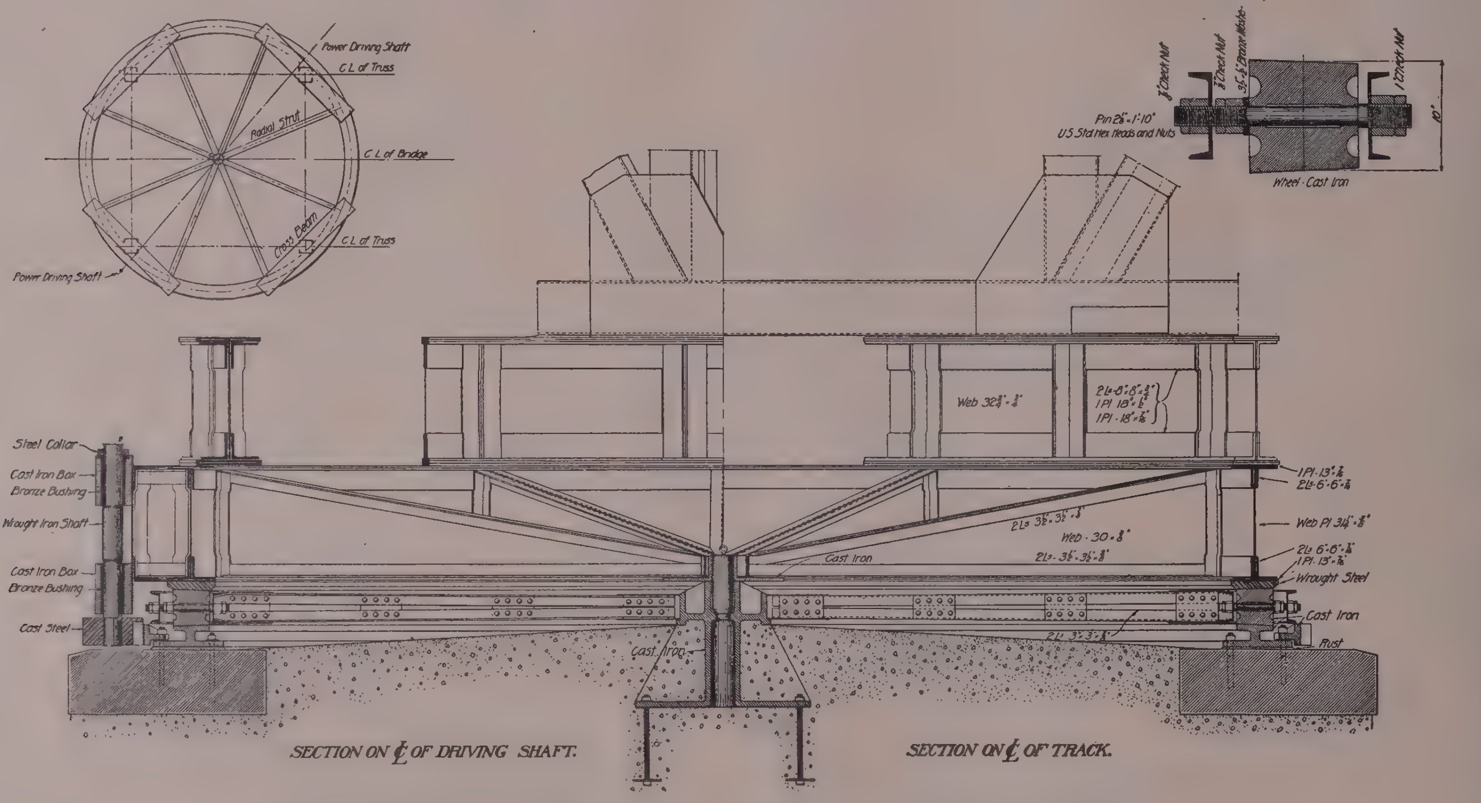
Most old draw spans were designed with adjustable radial rods, one end of each rod carrying a wheel. These rods were usually held to spacing by light bars or sometimes light channels. There have been several cases in which the binding of the nuts on the outer ends of the rods has caused them to revolve with the wheels, and the other ends being held, the rods were badly twisted, some even being twisted in two. This trouble is entirely obviated by the use of a stiff ring of channels held to gauge by batten plates between the wheels, and having stiff radial arms to the pivot. The wheels run on axles, adjustable radially, with tool steel washers to avoid danger of the nuts being turned by friction and thus altering the adjustment. In later designs these washers have been made of bronze, with a greater reduction of this danger. The simplicity of this turntable is very apparent when looking at the actual bridge, and for spans of about the size and weight of this one is perfectly satisfactory.

Since this bridge has been in service, there has been no difficulty with it, of any character. The only expense has been for oiling and keeping the pivot pier clean.

The writer's experience with center-bearing draw spans has been such as to prejudice him against them for spans of any magnitude. It seems to be difficult at any reasonable cost to proportion the pivot bearing so that it will not wear, and any wear on a pivot bearing is expensive to repair. On one draw the wearing away of the bronze bearing in the pivot allowed the upper and lower castings to rub, making the turning of the draw a very noisy operation, while the few wheels provided to steady the span while turning were overloaded and cut the circular track badly.

The design which, for ease of operation and repair and low maintenance cost has proved to be quite satisfactory, is shown in the drawing of the center for the single track draw span over the St. Croix River, near Prescott, Wis. The span is 368 ft. and is designed to carry a uniform train load of 7,000 lb. per foot, so that it is quite heavy. The beams bearing on the center casting are designed to carry one-half the dead load to the casting. The adjustment of the load is by means of shim plates between the beams and the top of the pivot. The adjustment is made during erection, the beams first being allowed to rest on the rollers with the center casting clear. The center is then jacked up until the drum just clears the wheels. After noting the amount of the lift, shims to half its amount are put in and the beams lowered to permanent bearing. This is of course only an approximate method. Attention is directed to the depth to which the center bearing is sunk into the masonry in this design also.

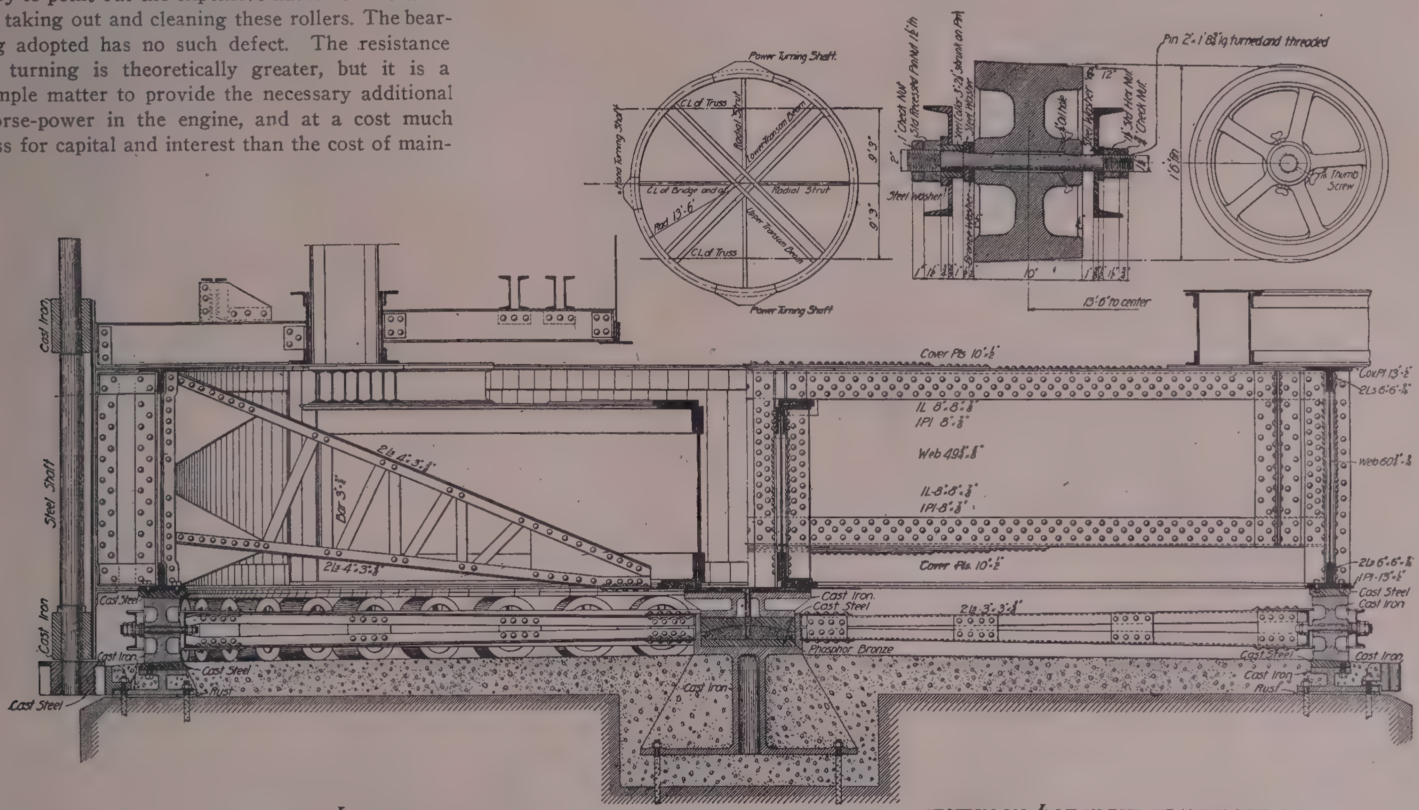
A number of spans have been built with center bearings of cone shaped rollers. The writer has had to maintain some of these, though at this



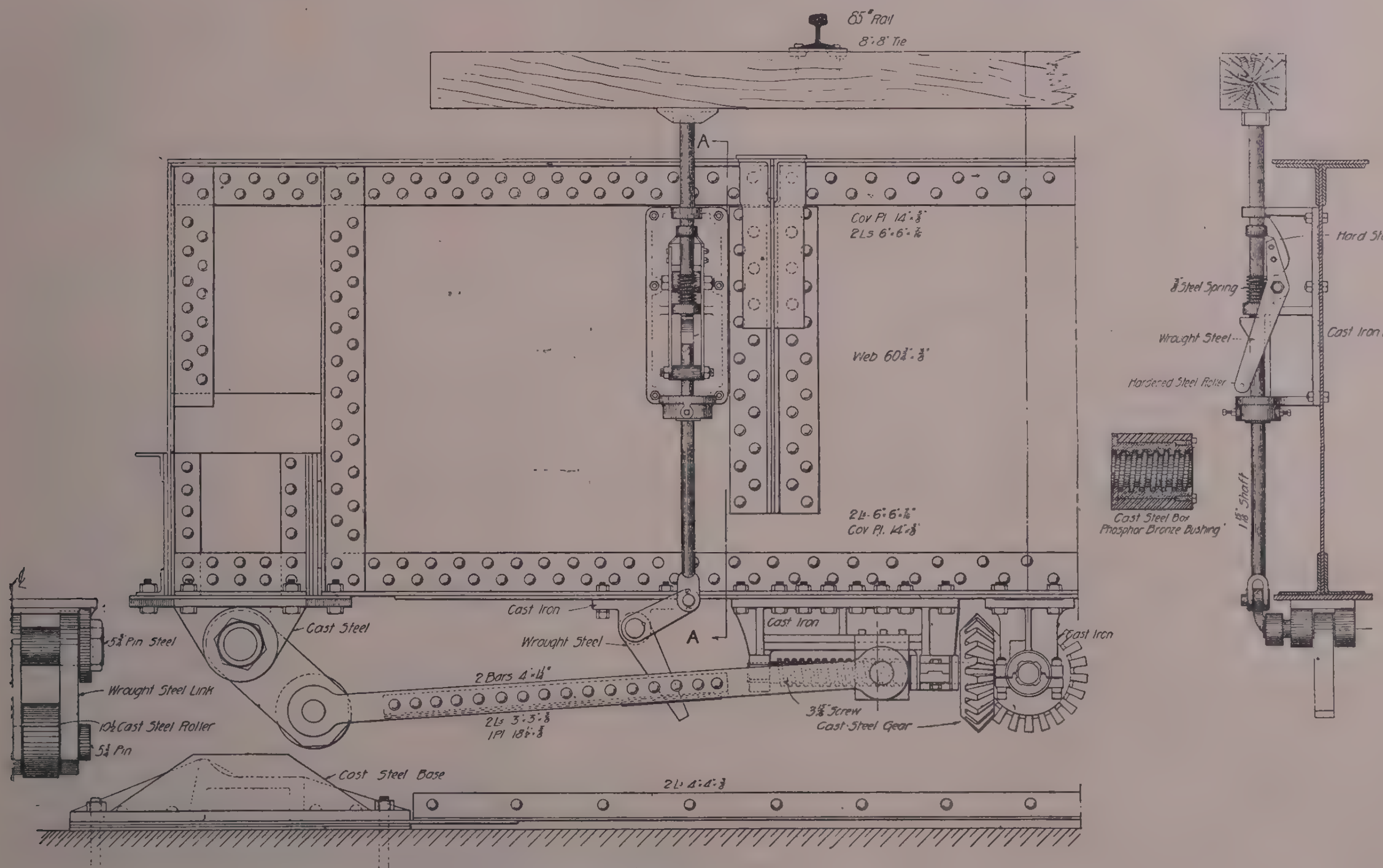
Turntable of Illinois River Bridge of the Chicago, Burlington & Quincy Railway.

writing all have been replaced. The experience gained in the maintenance of these conical roller centers has led to the design shown in the drawing of the St. Croix River bridge, involving lenses of steel and bronze. The cone rollers were found to wear unevenly, some of them never rolled, but slid on the bearings, although they were oiled and cleaned yearly. It is hardly necessary to point out the expensive nature of the work of taking out and cleaning these rollers. The bearing adopted has no such defect. The resistance to turning is theoretically greater, but it is a simple matter to provide the necessary additional horse-power in the engine, and at a cost much less for capital and interest than the cost of maintenance of the cone roller bearings, to say nothing of the freedom from trouble.

An oil hole is drilled through the saddle casting and the two upper lenses; a pipe running to the bridge floor is tapped into this and is capped with an oil cup, so that the bearing is constantly lubricated. As all parts of the bearing are made to a close working fit no dust can enter. These provisions for lubrication and for protection against dust are quite as important to the maintenance department as any structural provision, and they are points most frequently overlooked. In this connection the three oil holes in the hubs of the rim-wheels are worth notice, as it is possible for the oiler to lubricate the axle no matter what the position of the wheel. As it is gen-



TURNTABLE OF ST. CROIX RIVER BRIDGE, CHICAGO, BURLINGTON & QUINCY RAILWAY.



ELEVATION AND SECTION OF END LIFT OF ST. CROIX RIVER BRIDGE.

erally very much easier not to oil these wheels, than to do so, it is just as well to make the process as easy as possible.

The third drawing shows the details of the end lifting device for the St. Croix bridge. This is typical of practically all such devices in use on the Chicago, Burlington & Quincy Ry., but it differs in some few details from the first ones built of similar design.

The necessity for an efficient end lifting apparatus is apparent to every designer, and the writer's experience with wedges has led him to the conclusion that the difficulties in the way of getting adequate lift with them are too great. It is very likely that if the power of the engines had been greater there would have been no great difficulty, but it was found in practice that when the pedestals were set at an elevation required to give the desired lift the wedges could not be driven. When they were adjusted to such a height as to allow the wedges being driven, there was no reaction with a heavy train on the opposite arm of the span. The end lift shown has not failed to provide all required uplift and as its construction is such that its maximum efficiency of thrust is reached at the time of maximum load it is very easily handled. It is, of course, not in the least degree novel, but there are some features which are, so far as the writer is aware.

In the earlier forms of end-lifts the nut traveling on the horizontal screw was of steel, unbushed. At times of heavy duty, when a warm day caused the draw to deflect, this nut would sometimes become welded to the screw. Bushing with phosphor bronze has stopped this entirely. The vertical links which are under the chord end are beveled on the lower end to engage a similarly beveled surface on the casting. When they are in position they form a positive lock for the span and serve to bring it to exact line, a very difficult thing to do by means of the turning gear alone. The upper surfaces of these links bear against the steel casting which is riveted to the lower chord. As the upper pinholes in the links are made considerably larger than the pin the latter is not called upon to take any load while the lift is in action.

The connection of the two base castings by plates and angles is very necessary as it relieves the anchor bolts of the horizontal components of the lifting thrust.

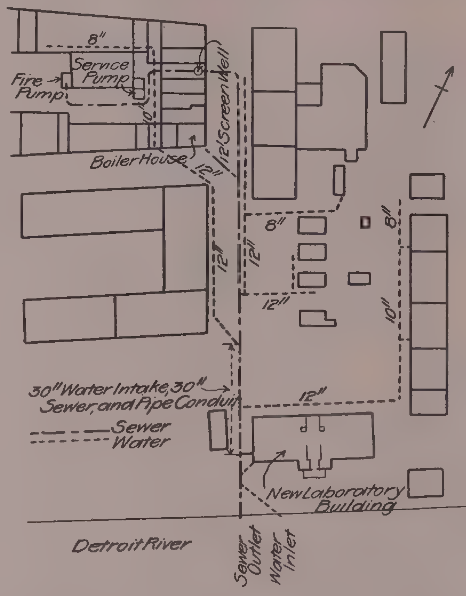
The rail-lift illustrated was, the writer believes, first employed by the late Geo. S. Morison. The lifting rod is cut, and the lower half free to follow the lever down as the span is lifted, until the operation is nearly complete, when a projection on the lower rod trips the trigger holding the upper half, with the result that the rails fall with a jar sufficient to drive them into place without further adjustment. The action of the combined apparatus, in first centering the ends, then lifting them and finally dropping the rails, is found to work admirably. While the rail-lift looks somewhat complicated there has been no difficulty with any which we have in use.

There are certain details of design of the structural part of draw spans which affect the question of maintenance to a considerable extent, and of which little or no mention is made in text books. It may be laid down as a general rule, that there should be absolutely no adjustable members in the trusses. All parts subject to complete reversal of stress, should be stiff members and have, as far as possible, riveted connections. No pin connections should be employed save for eye-bar members. This is particularly true of the connection between the end of the lower chord and the foot of the end post. The constant reversal of stress at this point, due to lifting and lowering the ends of the draw, very soon develops serious wear on pins and pin holes. With a properly designed riveted connection, no play being possible, there will be no difficulty.

In draw span design, perhaps to a greater degree than in any other, simplicity and rigidity are the prime requisites to economical operation and maintenance.

Conduit Construction Through Saw Mill Refuse.

The Detroit laboratories of Parke, Davis & Co., manufacturers of pharmaceutical supplies, are along the bank of the Detroit River about one mile above the central part of the city. They include over sixty buildings of various types of construction, which are mostly provided with heat, light and power from a central station included in the plant. The water supply was formerly all obtained from the distribution mains of the Detroit water works system, and the sewers of the plant were connected with the sewerage system of the city. In order to provide a supply of water for fire protection and other service for which a polluted water is suitable, which supply would be independent of the municipal system, a 30-in. cast iron main was laid from the river to wells from which the service and fire pumps of the plant are supplied. The sewage in the portion of the municipal sewerage system near the plant was liable to back up after heavy rains and flood the basements of the buildings, so an independent sewerage system, with an outfall leading to the river, was also built. A new laboratory building was being erected at the time the intake pipe and sewer were laid and had to be connected by a pipe conduit with the central power station of the plant.



Location of Trench, Parke-Davis Works.

The ground between the buildings of the plant and the present harbor line along the river was formerly submerged from 3 to 10 ft. by the river. This land had been reclaimed to a few feet above mean water level in the river with refuse from an adjacent sawmill. A street had been laid out at right angles to the river and across the reclaimed area, and was surfaced with clay laid on the sawmill refuse. Underlying the refuse is a stratum of hard clay. The water intake pipe and the outfall sewer were laid across the reclaimed area in the street. The sawmill refuse was entirely unstable. It was desirable to lay the outfall with the inside crown above the mean water level in the river, which is several feet above the natural clay surface and the bottom of the made ground. While the water pipe had to be laid below low water in the river, it could not be laid in the clay for its entire length without involving expensive trenches, considerably below the water level. The water pipe, outfall sewer and pipe conduit were, therefore, laid in the same trench, one above the other, and supported on timber grillages built on piles driven well into the clay below the sawmill refuse.

The water intake is a 30-in. cast-iron pipe extending 512 ft. from the river to a circular 12-ft. screen chamber. The outfall sewer is built of brick, is 34 in. in internal diameter and extends 300 ft. from the river to a manhole, with which the lateral sewers to various parts of the plant are connected. The pipe conduit is built of reinforced concrete. It is 4 ft. wide, 4.5 ft. high, and is placed in the same trench with the sewer and intake pipe for 210 ft. toward the river from the manhole on the sewer. The water pipe is placed with its invert 8 ft. below the mean water level in the river and 14 ft. below the surface of reclaimed area. The brick sewer is above the water pipe, with the intrados of its arch 10 ft. above the mean water level. The pipe conduit is just above the sewer. The arrangement of the intake, sewer and conduit and of the grillage on which they are built is shown in an accompanying illustration. The first 125 ft. of the intake pipe leading from the river is above the surface of the clay and the entire sewer is 3½ to 7½ ft. above the bottom of the fill of refuse.

A rock-filled timber crib 16 ft. wide was first built along the harbor line. A row of piles was driven on each side of the site of the trench for the various structures, the rows being 7 ft. on centers and the piles in the rows 6 ft. on centers. The piles were 30 to 35 ft. long, and at least 12 in. in diameter at the butt. They were driven until their tops were 2 ft. 10 in. below the grade line of the street and 5 ft. above the mean water level in the river. A 6x12-in. waling piece was bolted on the outside of each row of piles at the top. A row of tongue-and-groove sheeting was then driven on the outside of each row of piles, the rows of sheeting being 8½ ft. apart. The sheeting for 100 ft. back from the dock was 6x12-in. material and in the remainder of the work, 4x12-in. material. The sheeting pieces were from 14 to 20 ft. long and were driven until their tops were 1 ft. above the tops of the piles. The rows of sheeting were then bolted to the waling pieces on the piles and the trench excavated between them with little difficulty.

The cast-iron water pipe is carried by two 4x8-in. oak plank, placed transversely between each pair of piles in the two rows. The pipe sections are carried directly by planks and blocks on each pair of transverse timbers. The backfilling was omitted around this pipe. The sewer is carried by two 4x10-in. oak planks also placed transversely at each pair of piles. These plank are braced against the piles with 8x8-in. braces. The sewer barrel rests directly on a cradle of concrete laid on a heavy plank floor over the cross pieces between the piles. It was decided to include the pipe conduit in the trench with the intake pipe and sewer after the timber structure had been designed. A 10-in. steel I-beam was then placed on each side of the sewer barrel in the concrete cradle carrying the latter. A lagging of 2-in. plank was built up along the inside of each row of piles and on the cross timbers carrying the sewer. The space between these two rows of lagging and around the sewer was then filled with concrete, the pipe conduit being formed in the concrete over the sewer as shown in the cross-section. The conduit is reinforced with expanded metal which extends from the top of the sewer cradle on one side up over the top of the conduit and down to the top of the sewer cradle on the other side. The top of the conduit is also reinforced with twisted ¼x1-in. bars, placed transversely on 20-in. centers. The work on the intake, sewer and pipe conduit was completed in 1902 and all three structures have been continually in service since that time. No trouble has been experienced from the piles settling nor from the displacement of the conduit. The conduit is used for electric wires, and the pipes for compressed air, hot and cold water, steam flow and return systems between various buildings and the central power station of the plant; employees of the plant frequently pass through it and would soon locate any evidence of cracking of the concrete.

The intake has a screen opening in the face of the dock 50 ft. upstream from the outlet end of the sewer. The intake pipe and sewer are carried on separate timber structures for about 65 ft. at the river end, where the former is inclined upstream. The 12-ft. screen well in which the upper end of the intake pipe terminates is connected by a 20-in. cast-iron main with the suction wells of the service and fire protection pumps. A 12-in. gravity main 460 ft. long also leads from the 12-ft. circular well and supplies two vacuum pans by gravity. The service pump supplies water by sprinkling, flushing, for the boilers of the central station and other purposes for which a polluted water is suitable.

The plans and specifications for the intake pipe and sewer were prepared by Mr. George H. Fenkell, at present civil engineer to the commissioners of water works in Erie Pa., and approved by Mr. Clarence W. Hubbell, civil engineer to the board of water commissioners of Detroit. The work was done by Langley & Jeynes, concontractors of Detroit, under the direction of Mr. Fenkell. Messrs Donaldson & Mier, architects, of Detroit, designed the new laboratory and the reinforced-concrete pipe conduit leading to it.

Book Notes.

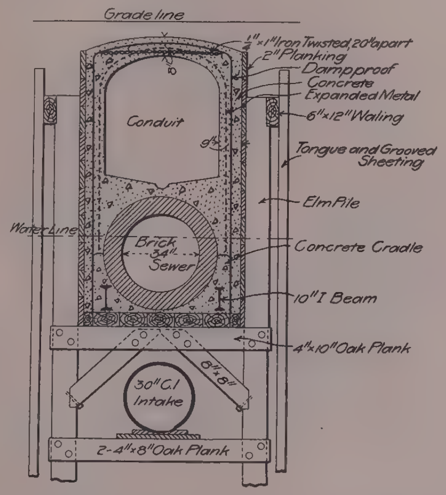
The "Municipal Year Book" for 1906 gives in about 700 pages of fine print a very satisfactory outline of the work of public authorities in the United Kingdom. Water, gas, and electrical supplies, sewage disposal work and other engineering features of city and rural activity receive attention, along with the housing of the working classes, education, municipal trading, public libraries, and similar technical subjects. The book has appeared annually for a number of years, a fact that indicates the value of its information to a large circle of readers. (Edward Lloyd, Ltd., Salisbury Square, London; 3s. 6d.)

The third volume of the report of the West Virginia Geological Survey under Mr. I. C. White, is devoted to the clays, limestones and cement materials of the State. It is written by the assistant state geologist, Mr. G. P. Grimsley, and is a book of 565 pages, sold at $4. The report begins with the clays. Their origin, properties and classification are explained, the manufacture of brick, tile, pottery and sewer pipe is described, the general extent and condition of the clay industries of West Virginia are outlined and the character of the product is stated. The same method of treatment is followed with limestone and cement. These resources are by no means fully appreciated as yet, and the book should prove of distinct value in calling attention to their importance.

The serious conflagrations in large cities during recent years have made it desirable to have more definite information concerning the resistance to fire of building stones. Accordingly the State Geologist of New York had a series of tests of eighteen different stones made by Mr. W. E. McCourt under the general direction of Prof. Heinrich Ries. Granite, gneisses, sandstones, limestones and marbles were examined by methods described in detail in Bulletin 100 of the New York State Museum. Illustrations of the samples before and after testing and elaborate tables of their condition during the progress of the tests are given. The pamphlet is sold by the State Education Department, Albany, for 15 cents.

A PRACTICAL MANUAL OF TIDES AND WAVES. By W. H. Wheeler. New York, Longmans, Green & Co.; cloth, large 8vo, 210 pp., $2.80.

The author of this volume is well known among engineers interested in river and harbor improvements as a student of this specialty who is not only able to temper his theoretical investigations with the knowledge gained by long practical experience in engineering work, but also as a writer who has the enviable gift of discussing a technical subject clearly. This latest work of his has been rather a pleasure than a task, to judge from some of the passages it contains, and its perusal will also be a pleasure to those who are interested in seashore phenomena in a general way, as well as to those whose duties require them to investigate tides. It is written for the engineer and not for the mathematician or physicist, and consequently does not attempt to outline the abstruse methods of analysis by which tides are computed and their phenomena explained.



Conduit Construction at Parke-Davis Works.

In the first chapter a brief statement is given of the importance of tides and the state of knowledge concerning them. The next chapter traces in an interesting manner the development of tidal science. Newton's equilibrium theory and Laplace's dynamical theory are outlined, Airy's analysis of tides is briefly explained, and a summary of other important contributions to the subject is given. The leading measurements of tides are pointed out and the studies of the Webers, Scott Russell and others are reviewed. In mentioning some experiments with models, some of them made by himself, Mr. Wheeler expresses the opinion "that models cannot be taken as reliable guides for carrying out works in an open sea or estuary, yet they are valuable aids as indicating results that may occur, and as affording suggestions that can be followed up and investigated." In the following chapter is given a summary of the laws relating to the generation and propagation of the tides, so far as they can be stated. The author points out how very far theory lags behind observation in the discussion of this class of phenomena, and then explains how the centripetal effect of terrestrial gravity and the varying attraction of the sun and moon cause the general tidal movement, which is modified by wind and atmospheric pressure.

The relations of the derivative tidal waves which ebb and flow every 6 hours and 25 minutes from the primary tidal wave moving continuously around the world in the Southern Ocean are described in one of the most interesting sections of the book. The rate of propagation of the tidal waves, the effect of expansion and contraction of the shore line, races, ripples, double and rotary tides and the inequality of the time and height of the two tides of the day are among the subjects discussed. This chapter on tidal waves is followed by one on tidal currents, which offer such serious problems to the navigator, and one on the mean level of the sea and range of the tides. The effect of wind and atmospheric pressure on the tides, which is discussed in chapter eight, is one of the most interesting branches of the subject, and it is also a very important one on account of its marked influence on the normal high-water level. Some of the observed results of wind which Mr. Wheeler records are also useful in discussing water levels in large lakes. The effect of atmospheric pressure is more difficult to determine and depends so much on local conditions that a discussion of it is hardly possible except in a very general way. In the discussion of river tides, which is the next subject, the author first explains the method of their propagation and states the reason of the unusual "blown tides," where, after the ebb has begun, the water flows up the river to a greater height than before and much above its calculated height. The distances to which tides are propagated are often very great, 900 miles from the sea in the Amazon, 450 miles in the St. Lawrence and 181 miles in the Hooghly, to quote but a few figures. In some rivers, moreover, the flood tide up the river rises higher than at its mouth; the range being 18 ft. at Quebec and but 9 ft. at the mouth of the St. Lawrence. Two problems of river tides that are of much importance are the transport of material by them and their effect on the salinity of river water, which are discussed at length by the author.

The subject of waves, so important to the engineer, receives much attention. It is one which has been much confused by the failure to recognize the many kinds of waves that exist. These the author divides into two groups, tidal and wind. Tidal waves he subdivides into three classes; the great primary tidal wave moving continuously around the Southern hemisphere, the secondary tidal waves caused by the first in the different oceans and seas, and tidal shore waves. Wind waves he divides into four groups; the deep ocean waves, the waves where the depth of the water and the fetch of the wind are limited, rollers and ground swells, and shore and breaking waves. The data on this subject brought together by the auhor are as interesting as they are important, and his criticisms of opinions often asserted in connection with engineering works to resist wave action deserve careful consideration. The abnormal waves due to seismic and cyclonic causes are discussed in a special chapter. The great waves following famous earthquakes are recorded in considerable detail, and the record of abnormal single waves is unusually complete. Cyclonic waves are similarly explained. Tidal bores are discussed in a separate chapter, and special attention is drawn to a remarkable illustration of the bore in the River Trent.

The last three chapters are of a directly practical character. In them the author first explains the general nature of local tide tables and the method of preparing them. He then takes up the much-debated subject of secondary undulations, seiches and the undulations preceding storms, and gives some notes concerning their value in certain localities as an indication of causing storms. Finally, he discusses the tides as a source of power, a subject he summarizes as follows: "Any attempt to utilize the tides on a large scale with existing mechanical appliances cannot be considered as coming within the lines of commercial economics."

The book closes with a voluminous bibliography and a number of tables. The volume is so comprehensive and well written that it will be enjoyable not only to engineers but also to all who spend their vacations at the seashore and take an interest in the tidal phenomena to be observed there.

Letters to the Editor.

BOILER SETTINGS.

SIR: I have read with much interest an article entitled "Improving the Boiler Plant at the Stratford Hotel, Chicago," in your issue of April 21. The improvement made by Mr. A. J. Saxe is a very good one, and, as you no doubt know, has been advocated by me since 1883.

In 1882 I built the first Heine boiler in this country, and it was set in the style adopted by all builders of sub-horizontal water-tube boilers, i. e., with baffles or flame plates set across the tubes, so as to compel the travel of the gases up and down, or practically at right angles to the tubes. By means of a fire brick arch projecting in front of the boiler I accomplished practically smokeless combustion, and gained the prize, offered by the St. Louis County Fair, for the best furnace for the prevention of smoke under boilers using Illinois bituminous coal. In the course of my experiments, however, I found that there was no advantage and many disadvantages in the vertical baffling.

Since 1883 every Heine boiler of the many thousands built by us, has been built with horizontal baffling, which I then originated. Somewhere about 1884 I read a paper advocating this horizontal baffling, before the American Institute of Mining Engineers in convention at Pittsburg. I gave as my reason for preferring it to the simple statement that you must first produce complete combustion in a hot chamber before cooling the gases by contact with the heating surface of the boiler. This reasoning was generally acquiesced in.

I call your attention further to The Engineering Record of February 19, 1898, page 258. It is gratifying to see practical men like Mr. Saxe adopt this rational style of setting in boilers where the old incorrect type had first been installed.

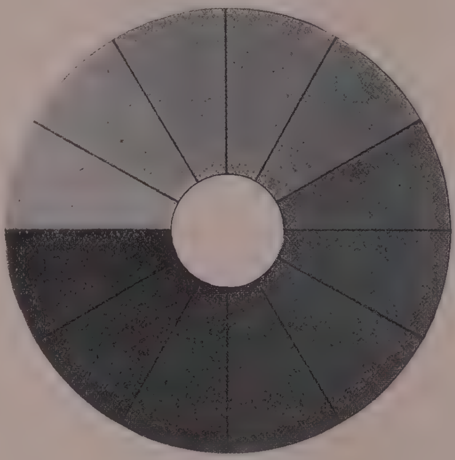
Very truly yours, E. D. MEIER.

New York, April 25.

[The article referred to by Col. Meier was written by Mr. George H. Barrus and described tests made on two 200-h.-p. horizontal water-tube boilers, set side by side in one battery of brickwork. In one boiler the arrangement of the flame plates was such that the direction of motion of the products of combustion was nearly at right angles to the length of the tubes, and in the other nearly parallel to their length. Furthermore, in one the products of combustion passed immediately upward into the tube spaces, whereas in the other they passed nearly horizontally for a considerable distance before coming in contact with the main heating surface. The boilers were duplicates, except in the features noted, and each contained 120 4-in. tubes, nominally 16 ft. long. The grates in each case were 5½ ft. long and 9 ft. wide, thus giving 50.5 sq. ft. of grate surface for each. The area of heating surface was 2,270 sq. ft. in each boiler, giving a ratio between the heating surface and grate surface of 45 to 1. The draft area between the tubes on the No. 1 setting at the entrance to the chimney flue space was 15 sq. ft., or 30 per cent. of the area of the grate surface. The draft area at the corresponding point in the No. 2 setting was 10 sq. ft., or 20 per cent. of the area of the grate surface. The draft area pertaining to the forward horizontal passage of the gases through the tubes was 30 sq. ft., or 60 per cent. of the area of the grate surface. In the case of the No. 2 setting an air pipe was provided just back of the bridge wall, so arranged as to supply a certain amount of air to mingle with the gases, which was well distributed over the entire width of the combustion space. This pipe was 7 in. in diameter and the equivalent of about half the area of the pipe, or 20 sq. in. of opening was used for the introduction of the air. These boilers were used for a plant which required steam about eleven hours each day. The balance of the time the fire was banked and the pressure fell to zero. The tests were made with a running start and stop, and they commenced about one hour after the boilers had become heated to their working condition. The coals used on the tests were Big Muddy lump and Collinsville lump, both obtained from Illinois and of the highly volatile class. In the case of the Big Muddy coal the horizontal pass and the admission of air increased the efficiency from 61.6 to 67 per cent., and in the case of the Collinsville coal the horizontal pass and the increased air supply increased the efficiency from 58.6 to 64.9 per cent.]

SMOKE DIAGRAMS.

SIR: In your issue of April 21 you give an abstract of a paper by Mr. Albert A. Cary on the prevention of smoke, and describe therein diagrams or scales for the determination of the density of smoke. Perhaps the accompanying diagrams may interest your readers; it is one I made for my own use and is so easily reproduced as to afford a very handy means for comparative tests.



A Smoke Diagram.

On a small piece of Bristol board, or any clear white drawing paper, two concentric circles with diameters of about 1 and 4 in. are drawn and twelve radial lines 30° apart are drawn cutting them. Eleven of these sectors are then tinted with Chinese ink, using 5 drops of Guenther Wagner's water-proof pearl ink thinned with 150 drops of water. Ten of the sectors get a second coat, nine get a third coat and so on, care being taken that a coat has dried thoroughly before the next one is applied. The inner circle is then cut out and the diagram fixed to a piece of cardboard. [In the accompanying reproduction of one of these diagrams the effect of the half-tone engraving process has been to darken the light shades and lighten the dark shades.—ED. Eng. Rec.]

In this way I get a scale of twelve densities and by holding it at arm's length and looking through the central hole at the smoke, the comparison is readily made. The Ringelmann and the Bryan Donkin charts may be more scientific, but their use is certainly less easy and require more skill and practice. Yours truly,

Wilkensburg, April 22. K. A. MUELLENHOFF.

STRIKING CENTERS.

SIR: Kindly have the following question decided through your magazine: Is it better for arches to have the centers drawn as soon as the work has been finished, or shall the centers remain in place until the mortar in the joints has set? Our city is building a brick sewer, and it is claimed that the joints close up better and strengthen the arch if the centers are removed at once after the work is done. ENQUIRER.

FIVE-CENTERED ARCHES.

SIRS: The graphical method of laying out the five-centered arch proposed by Mr. A. Swartz in your issue of April 14 is very ingenious and is similar to that stated in Warren's "Stereotomy" (1888), Plate II, Fig. 21. Another simple analytic solution is there suggested, and a similar hint is given in Alexander and Thompson's "Elementary Applied Mechanics," page 474. Both of these are probably based on Rankine's solution of this problem on page 420 of his "Civil Engineering." This is in turn based on well-known properties of the ellipse which the curve under consideration resembles, although it also approximates Rankine's hydrostatic arch.

At the extremity of the minor axis the radius of curvature in the ellipse is a third proportional to the semi-minor and semi-major axes. Therefore, $CA:CD::CD:KA$ and $R_3 = KA =$ (minor semi-diameter)^2 $\div$ (major semi-diameter).

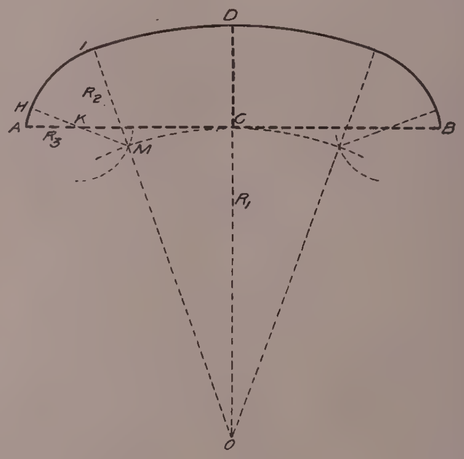


Diagram for Five-Centered Arch.

At the extremity of the major axis the radius of curvature is a third proportional to the semi-major and semi-minor axes. Therefore, $CD:CA::CA:OD$ and $R_1 = OD =$ (major semi-diameter)^2 $\div$ (minor semi-diameter).

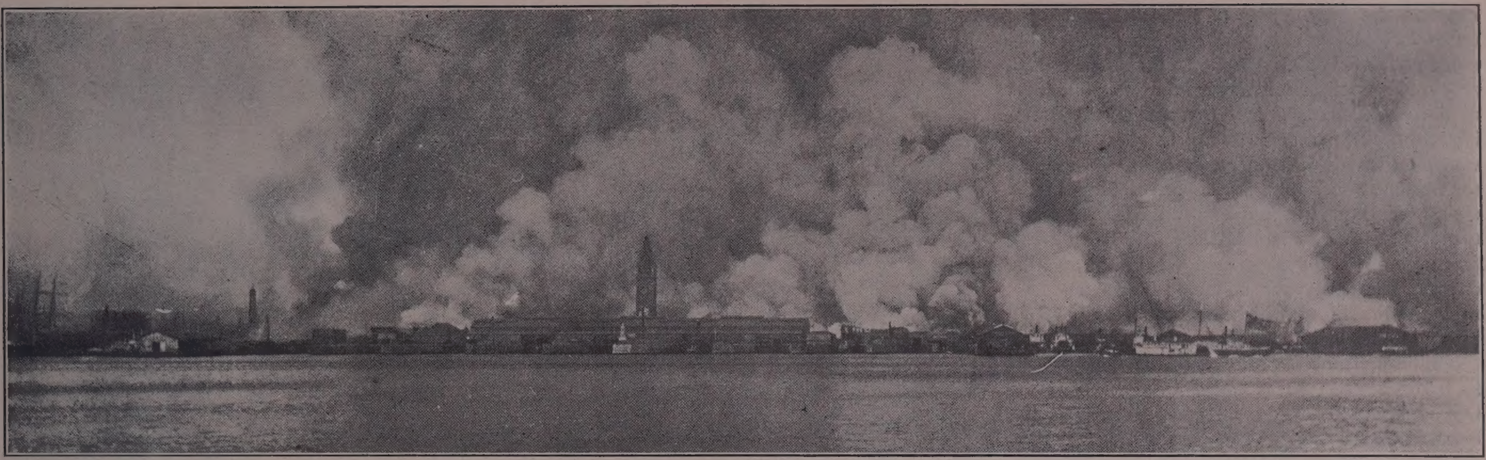
$R_2 =$ semi-minor axis $= CD$.

The point M is found at the intersection of an arc having a radius OC (equal to $R_1 - CD$) and a center, O, with an arc having a radius KM (equal to the minor semi-diameter $- R_3$,) and a center, K.

A slightly different curvature may be found by making R_2 a mean proportional to R_1 and R_3, from which it can be readily shown that R_2 is also a mean proportional to the semi-axes. The position of the center, M, for this solution is determined by methods similar to those proposed by Mr. Swartz, or by striking arcs as above, but substituting the mean proportional for the semi-minor diameter. Very truly yours,

Malden, Mass. CALEB MILLS SAVILLE.

THE BRITISH CHEMICAL INDUSTRY is reported by the London "Times" to be less prosperous than formerly. In four years there has been a decline of 25 per cent. in exports of alkalies and 34 per cent. in bleaching materials.



View of the Ferry House and Burning City.

A PICTORIAL RECORD OF THE RESULTS OF EARTHQUAKE AND FIRE AT SAN FRANCISCO.

The Well-Built Steel Frame Building Shown to Resist Earthquake and Fire in the San Francisco Catastrophe.

By Maurice C. Couchot, Assoc. M. Am. Soc. C. E., Alameda, Cal.

At 5:13 a. m. on Wednesday, April 18, a violent earthquake shook San Francisco and vicinity causing great damage to property, as the readers of The Engineering Record are well aware. Only the fact that this cataclysm occurred at this early time of the day kept the loss of life so fortunately small, in comparison with what it would have been had the shocks occurred during the working hours or even during theater time.

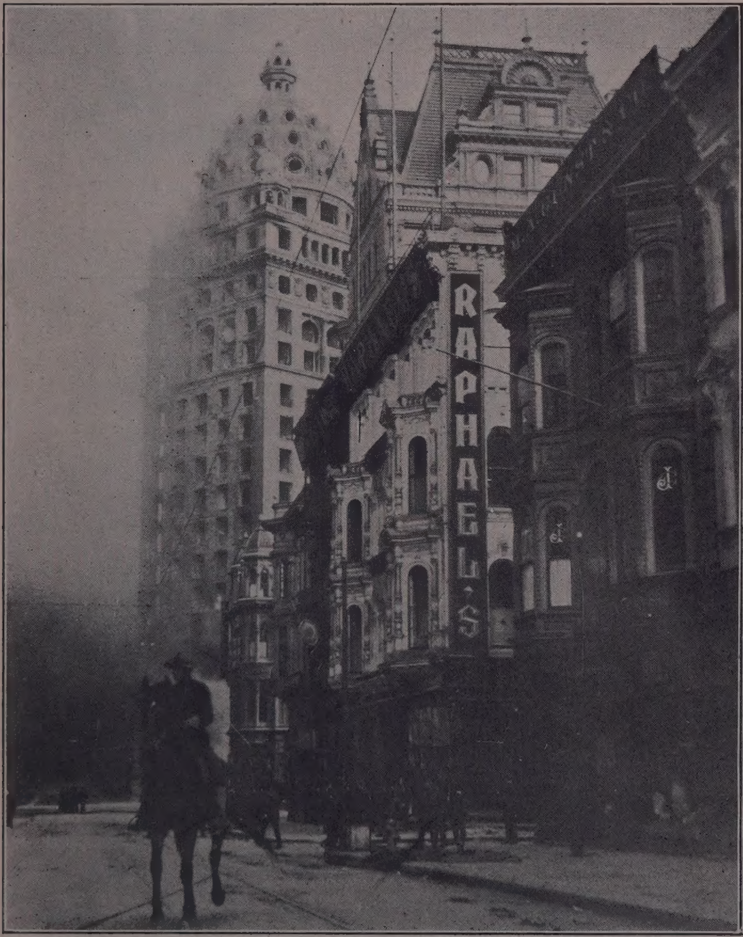
This earthquake started a number of fires in different parts of the city, but the place would probably have been saved if the water supply had not been cut off entirely by the seismatic disturbance. I would say at the outset that this was the greatest damage done the city by the earthquake. I would also say that great credit is due the brave firemen, soldiers and citizens who in the face of one of the greatest catastrophes the world has ever seen, fought, inch by inch, the most terrible combination of destructive elements that can be imagined.

Only those who saw it can have a complete comprehension of this disaster. I was fortunate enough, in one sense, to be able to get into San Francisco a couple of hours after the shock and before the fire had gained its unchecked headway and was, therefore, able to see the damage caused by the earthquare independently of the damage afterwards done by the fire.

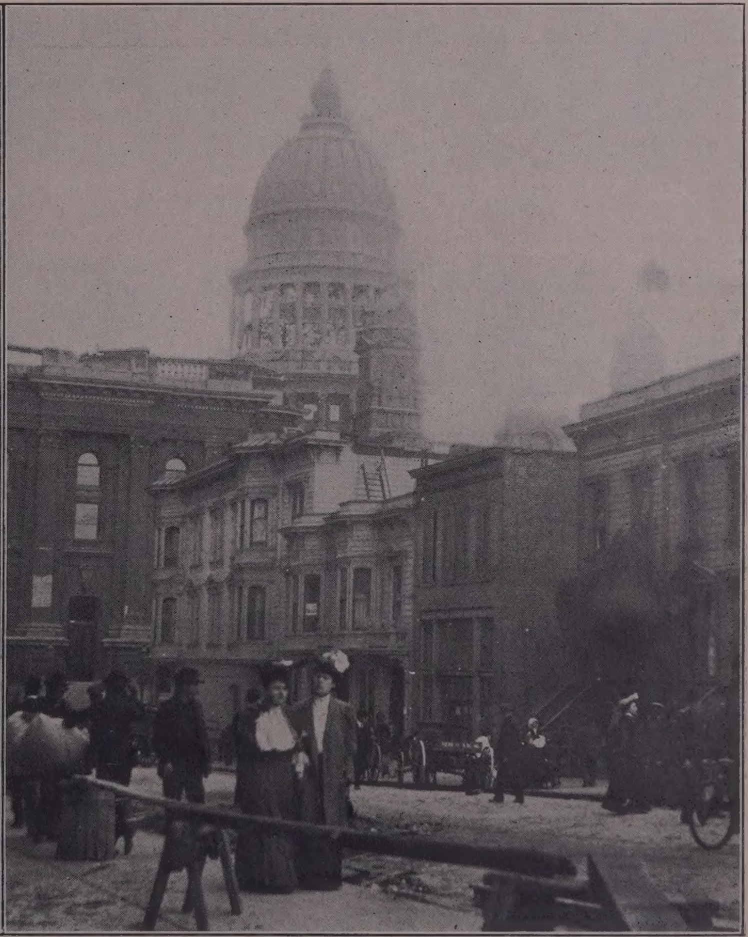
The Baltimore fire had demonstrated that the steel-cage construction, when properly designed and properly fireproofed, is practically resistant to fire. The San Francisco earthquake has also proved, so far as can now be ascertained until a more minute investigation can be made, that the steel-frame construction, where properly designed, can take care of its own in such a contingency.

All steel-frame structures known locally as Class "A" buildings appeared structurally intact after the earthquake, as can be seen from photographs. None was thrown out of plumb, or had been shifted, or was twisted as rumored; but all showed that they had been subjected to great racking strains. These strains were possibly taken care of by the steel frame and what was visible was either a crushing, spalling or splitting of some of the stone, brick or terra-cotta facings.

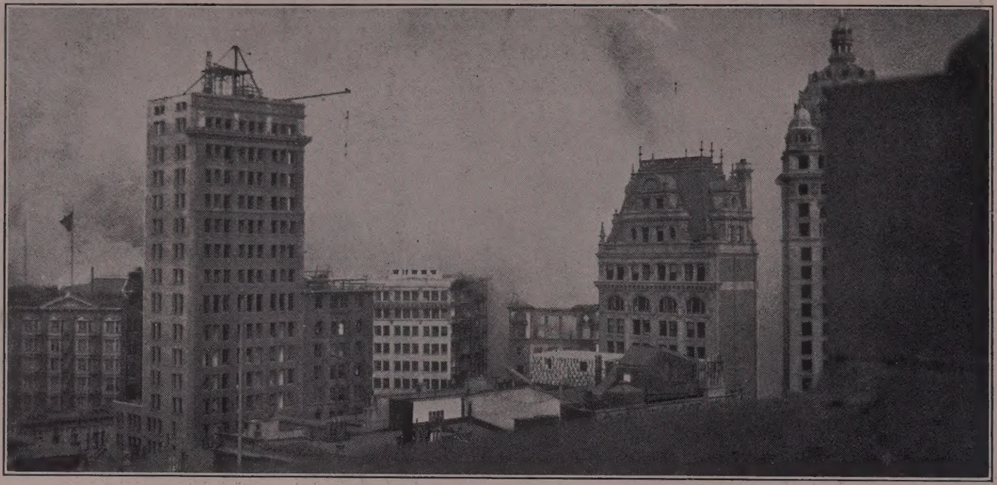
The characteristic of this was a fracture in the form of an X, which is perfectly well defined in the photographs of the Chronicle Build-



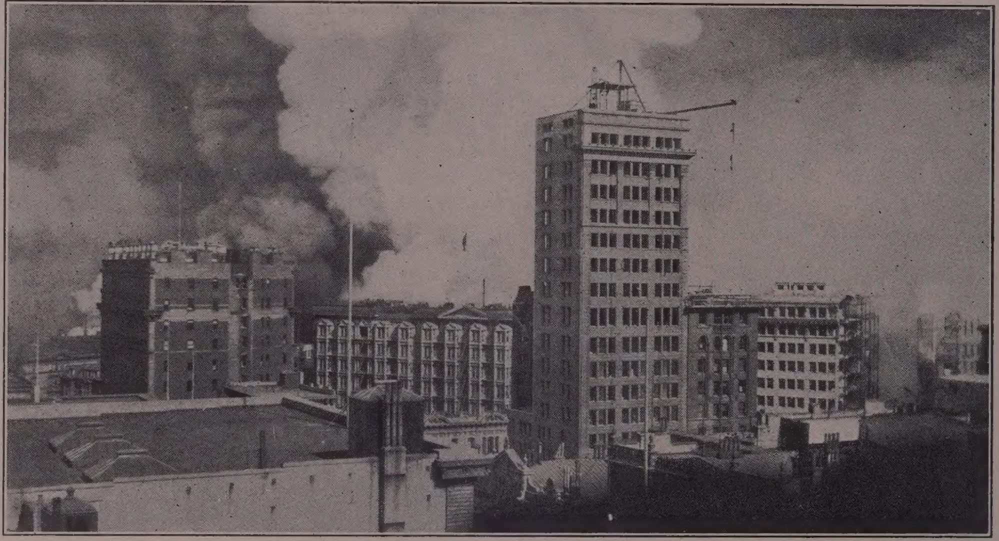
View of the Call Building while Burning.



View of City Hall after the Earthquake.



Palace. Chronicle. Monadnock. Examiner. Mut. Sav. Call.



Crocker. Palace Hotel. Chronicle. Monadnock.

ing and the Fairmount Hotel (although very much lost in the engravings on account of the effect of the half-tone screen). This characteristic appeared sometimes in the base of the buildings at the corner pier, as in the James Flood Building and the St. Francis Hotel, when the stone was split, and in the Fairmount, or as in the case of the Chronicle Building, in the center piers in the eighth, ninth, tenth and eleventh stories, or in the panel filling as in the Atlas Building. These fractures are easily accounted for by the racking effect of the earthquake inducing diagonal strains in both directions, which could not be resisted by the stone, brick, or terra-cotta facings.

Nothing yet can be said as to the effect of the shock upon the foundations of all the large buildings, but from general appearance it is not believed that they have been hurt.

In regard to the steel frames, valuable information can now be obtained from a number of steel frames which were being erected at the time of the cataclysm, although the strains induced in them were not so severe as in the finished buildings, as their inertia was a great deal less and they were more flexible.

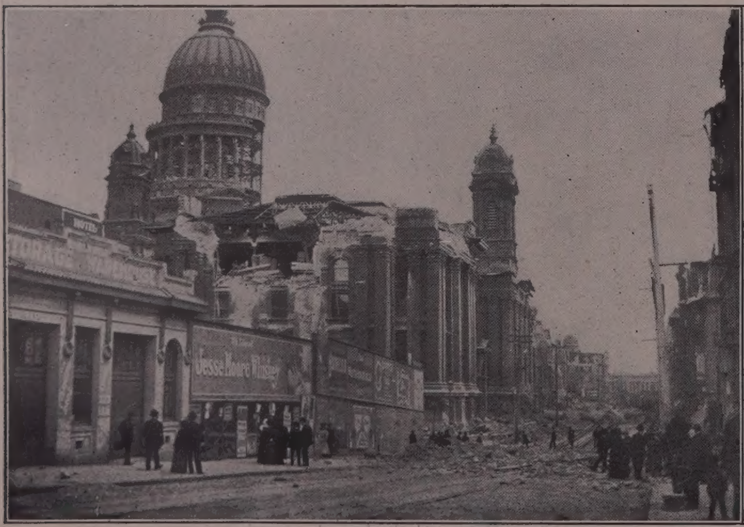
Another point brought out was that the stiffer the frame was, the less the damage. The Shreve Building, a very fine structure of eleven stories having a well-designed steel frame, was practically intact after the shocks, only a few patches of plaster having been knocked down. The Flood Building of eleven stories, the Crocker Building of eleven stories, the Union Trust Building of ten stories, the Mutual Savings Bank of twelve stories, the Call (Spreckels) Building of nineteen stories (the pride of San Francisco and what was admitted the most beautiful office building in the world), the Mills Building of ten stories, the St. Francis Hotel of eleven stories, the Merchants' Exchange of fourteen stories, the Kohl (Haywards) of eleven stories, all these magnificent buildings were practically intact after the earthquake and a credit to the architects and engineers who constructed them. I may also say that all dams and power plants in the interior of California have not been disturbed by the earthquake.

In regard to the fire, we have gone through the same experience as Chicago, Boston and Baltimore have suffered before us.

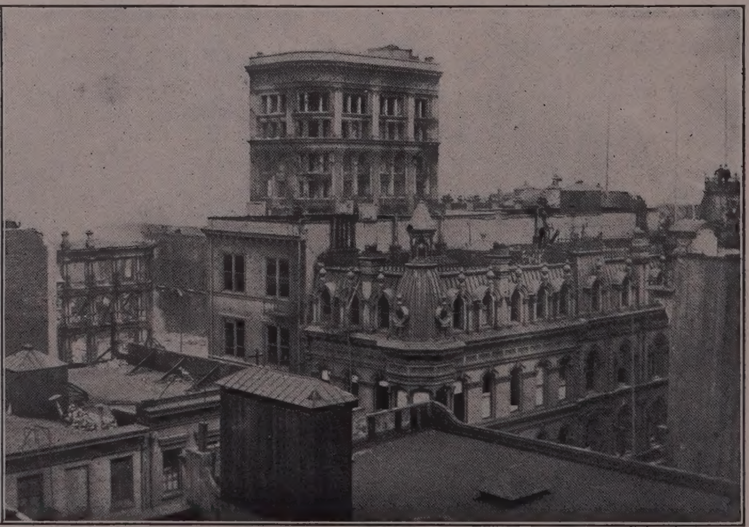
Steel-frame buildings are not entirely fireproof as they are now generally built. Where the steel frame is well protected only that much of the building can be said to be fireproofed; the same may be said of reinforced concrete floors where they are used, but all the rest of the building is destroyed by fire. Tile flooring was next to worthless. Tile partitions as well as plastered partitions were generally destroyed, the best one being the 2-in. solid. In fact, I have not seen any partitions that stood the fire. The marble, granite and stone facings all went to ruin under fire. They are very beautiful, but they can not be used if we wish to have lasting buildings. Pressed brick stood the best of any facing material and terra-cotta trimmings, when not too much loaded with decoration and not glazed, but well burnt and consistently designed (I mean able to take unequal expansion), came next.

Common brick may be dangerous, as well in an earthquake as in a fire. I have seen a few examples of good brickwork and they are now standing, a credit to their builders, but I must also say that I have seen an awful lot of bad work in brick. All Class "B" and "C" buildings, having brick walls with wooden joists and partitions, were badly wrecked by the earthquake and absolutely destroyed by fire. Such buildings above four stories in height should not be permitted anywhere. All buildings above that should have a steel frame.

A word about reinforced concrete construction. There was but one example in San Francisco at this time, this construction having been kept out by the existing laws. This building was



The City Hall after the Earthquake.



The Mutual Life Building after the Fire.

in course of construction and its concrete portion is intact, while the brick walls are entirely ruined by cracks and will have to be replaced. This was built by the Kahn system. Another small example in Alameda escaped intact, while a brick building fifty feet away has crumbled down.

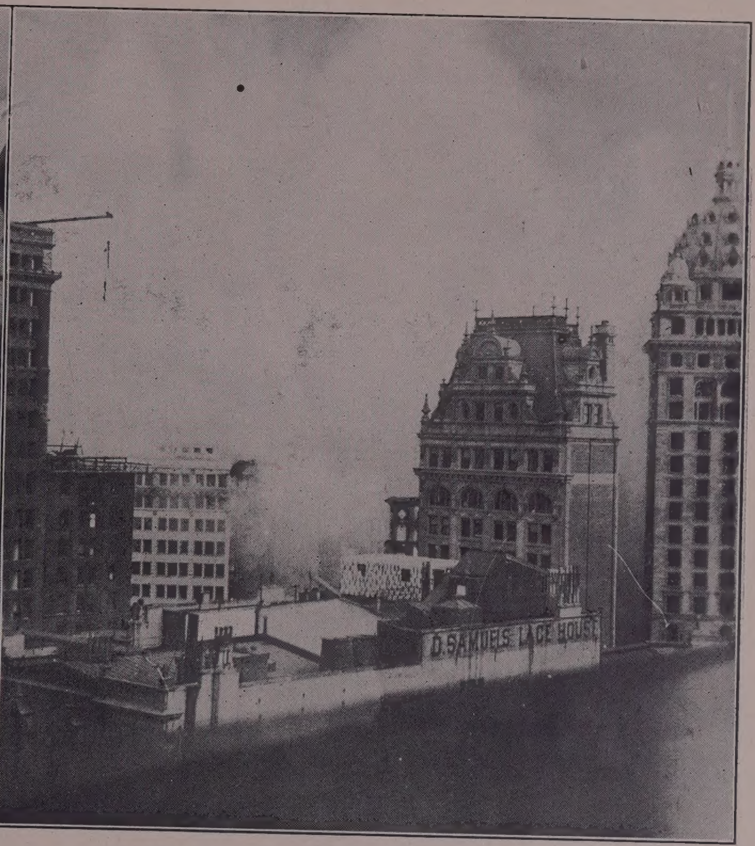
The lesson we learn from this terrible calamity is a very costly one and should not go to waste. San Francisco will be rebuilt on a greater and grander scale; you simply cannot down this spirit. But new city ordinances must be enacted; a stricter inspection must be maintained and enforced; an efficient Board of Public Works, constituted of engineers, architects and builders, must be chosen and kept clean of politics. Men for technical places must be chosen for their integrity and their knowledge and not for the number of votes they can control.

I would like to offer the following suggestions in reference to Class "A" buildings (so-called fireproof), for the purpose of bringing them closer to that ideal condition.

The foundations should be figured on a low rate of loading per square foot and for dead load only, possibly adding one-fifth of the live load for office, hotel or similar buildings, and all of the dead and live loads for warehouses, shops, factories and heavy construction. The foundation should be entirely of concrete, either plain or reinforced, and in a mixture not leaner than 1:2½:5, using only the best Portland cement and materials. The steel frame should be designed for stiffness as well as it is now designed for dead, live and wind loading. All the spandrel girders should be made as deep as the space between the window head and the window sill above. All connections of these girders and cross girders taking floor loads and wind strains should be as deep as permissible and all connected with gusset plate connections. No more shelf connections should be allowed except for floorbeams.

All steel, in the broadest meaning, should be absolutely incased in solid concrete 2½ to 3 in. outside of metal. All wall panels, all floors, all

Fire in Paper Warehouse



Monadnock. Mut. Sav. Call.

View as Call Building Caught Fire.

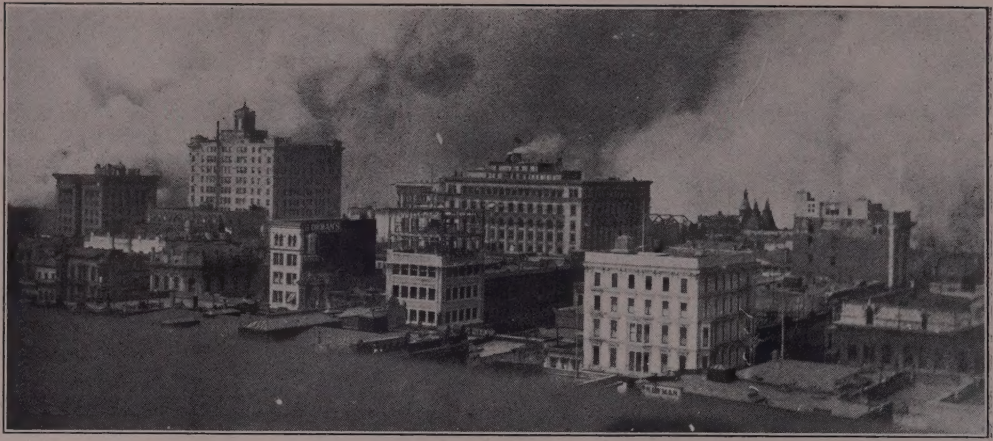
View near Grand Opera Building.

partitions should be of reinforced concrete, tied to the steel frame. All lights in partitions, side or rear walls should be wired glass and all outside windows should be provided with some metallic shutters and sashes.

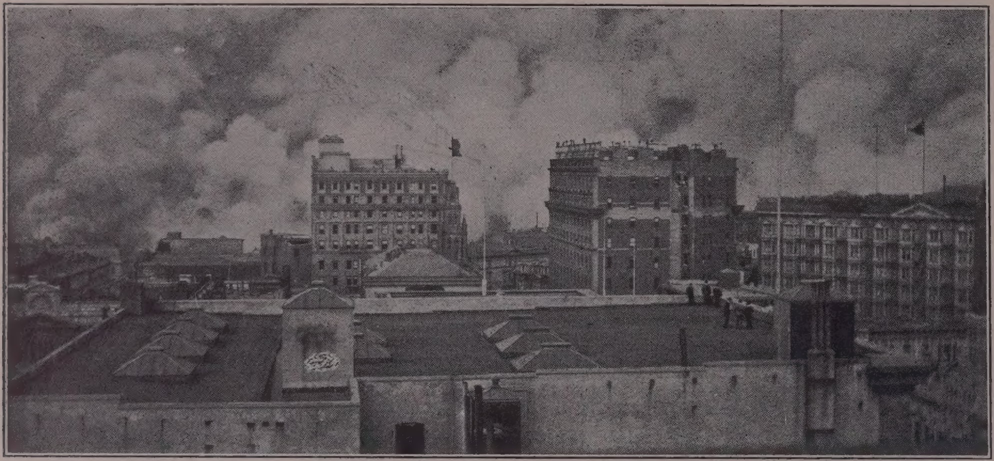
The importance of the suggestion in this last paragraph was well impressed upon me as I passed in front of the new Telephone Building on Bush Street. The architect of the building should be highly praised. That building was absolutely fireproofed for an outside fire, but somehow the fire started inside, how, I cannot yet explain; but the wired glass, metallic sashes and shutters did their intended work and were still in place after the conflagration.

All stairs and elevator shafts should be isolated and completely enclosed, making it impossible for the fire to reach from floor to floor through this channel. Also, the so-called firewall of brick and the projecting stone cornice should be done away with as they are a danger. A metal cornice with a reinforced concrete firewall should be used instead. A water curtain through some piping around the cornice should be installed.

As a matter of fact, no wood should be used, even for flooring, and some substitute as linoleum, xolith or similar substance, should be used when possible. All doors should be metal. All casings should be light metal, not covering some wood but should be filled with some plastic substance. When brick is used it ought to be bonded at every other course with a full course of headers. I saw all the veneer in the back light court of a large building stripped from the second floor to the eleventh. This veneer was only bonded to the backing by a clipped course every tenth course, the most abominable piece of work I ever saw. All pressed brick and common brick ought to be of the same size, so as to permit good bonding. Lime mortar as used now is worthless; it goes to sand in a fire. All first-class brickwork should be laid in cement mortar, with only enough lime added to permit its easier working. No metal bond should be permitted except in cement mortar.



View taken after the Earthquake and before the Fire.



View taken at 2 P. M. on Wednesday Afternoon.

From Mr. W. C. Ambrose, M. Am. Soc. C. E.

In the matter of the earthquake it seems well established that the best steel construction sustained no damage, and next to that was well-built wooden houses. The only damage to them was in case of comparatively tall, cheap structures, which were badly shaken, and in a few cases they were much damaged.

The poorest buildings to withstand the earthquake were of brick or stone, the latter being the better because the constituent pieces are heavier. Many brick buildings were totally demolished, and so far as I can learn nearly all the deaths from earthquake were in them. In some cases all the sides collapsed; in others only one or more collapsed. The fire walls above the roofs in most cases fell down, and nearly all brick chimneys are broken off at the roofs.

Immediately after the earthquake fire broke out in many places. The fire was much more disastrous than the earthquake because San Francisco, aside from the business district, is nearly all built of wood. The water mains were nearly all broken by the earthquake, leaving the city practically without water for fighting the fires.

In the best steel construction the framework was practically uninjured, and where there was little or no woodwork the buildings will be used again in a few days. In fact, the damage was directly proportional to the amount of wood in the building. In the case of brick buildings more combustible material was used in the construction, and this of course was all burned. In wooden buildings, which included the great majority, the loss was complete. From the first, buildings were blown down by dynamite under the direction of army officers, with the hope that the fire might be isolated, but this was not successful until Van Ness Avenue and Dolores Street were reached, where the fire was checked. These are about 90 ft. wide, among the widest in the city.

Contrary to popular belief, the tallest new buildings made the best showing, both in fire and earthquake, and there seems to be less vibration near the top of tall buildings than near the bottom.

Scene in the Burned Commission House District.

In the matter of fire, the lesson seems to be that there should be very wide streets at intervals to check a general conflagration.

Electric Steel Refining is now conducted commercially at the works of the Halcomb Steel Co., in Syracuse, the Heroult methods being used. When the electric furnace was started six weeks ago, the charges were cold, but when regular operation began a week later, molten super-oxidized steel was supplied from a Wellman furnace.